UNCLASSIFIED

AD NUMBER

AD871350

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to DoD only; Administrative/Operational Use; MAY 1970. Other requests shall be referred to U.S. Army Land Warfare Laboratory, Aberdeen Proving Ground, MD 21005.

AUTHORITY

AMSAA ltr, 1 Oct 1974

THIS PAGE IS UNCLASSIFIED

TECHNICAL REPORT NO. LWL-CR-06C66A

AIRCRAFT MOUNTED PERSONNEL DETECTOR CHEMICAL

Final Phase IV Report
Contract No. DA-18-001-AMC-983(X)

By

Ordnance Systems
General Electric Company
Pittsfield, Massachusetts 01201

May 1970

EACH TRANSMITTAL OF THIS DOCUMENT OUTSIDE THE DEPARTMENT OF DEFENSE MUST HAVE PRIOR APPROVAL OF THE U. S. ARMY LAND WARFARE LABORATORY.

U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

TECHNICAL REPORT NO. LWL-CR-06C66A

AIRCRAFT MOUNTED PERSONNEL DETECTOR CHEMICAL

Final Phase IV Report
Contract No. DA-18-001-AMC-983(X)

By

Ordnance Systems
General Electric Company
100 Plastics Avenue
Pittsfield, Massachusetts 01201

May 1970

U. S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

PRECEDING PAGE BLANK - NOT FILMED

CONTENTS

Section	Page
ABSTRACT	ix
1—Introduction	1-1
1.1 Purpose of the Report	1-1
1.2 Program Summary	1-1
1.3 Content of the Report/Volumes 1 and 2	1-1
1.4 AMPD Equipment Description	1-2
1.5 AMPD Function	1-2
2—System Configuration	2-1
2.1 System Configuration/1 January 1967	2-1
2.2 Design Changes and Modifications	2-2
2.2.1 Plotter	2-2
2.2.2 Recorder and Magnetic Tape Printout	2-3
2.2.3 System Noise—Filter Box (Figure 2-1)	2-5
2.2.4 Accelerometer	2-7
2.2.5 Precise Wind Solution	2-7
2.2.6 Self-Destruct	2-11
2.2.7 Ground Isolation Changes	2-11
2.2.8 Detectors	2-13
2.2.9 Converter Changes	2-16
2.2.10 TMG Display—VSI	2-17
2.2.11 Synchro Loading	2-17
2.2.12 Turbulence Propellers	2-19
2.2.13 Log Amplifier Change	2-29
2.2.14 Optical Tape Reader	2-34
2.2.15 Program Changes	2-34
2.2.16 Playback Tape Reader	2-35
2.2.17 Analyzer Modifications	2-35
2.3 Final Configuration	2-41
3—Phase IV Program Events	3-1
3.1 Scope/Phase IV	3-1
3.2 System Design	3-1
3.2.1 Pods	3-1
3.2.2 Control and Display	3-1
3.2.3 Vibration Effects	3-18
3.2.4 Electronic Equipment	3-18
3.2.5 Environment	3-18
3.2.6 Fungus Coating	3-21
3.2.7 OV-1 Cockpit	3-22
3.2.8 Ground Rules	3-23
3.3 Subsystem Design	3-23
3.3.1 Pod Design	3-23
3.3.2 Chemical Subsystem	3-25
3.3.3 Navigational Subsystem	3-46

CONTENTS—Continued

Section	Page
3.3.4 Compass Subsystem	3-52
3.3.5 Meterological Subsystem	3-53
3.3.6 Plotter Subsystem	3-54
3.3.7 Data Handling Subsystem	3-97
3.3.8 Power Subsystem	3-104
3.3.9 Computer Program	3-109
3.4 System Fabrication	3-111
3.5 System Test (Summary)	3-111
3.5.1 Power Consumption Check	3-111
3.6 Installation in Aircraft	3-142
3.7 System Checkout in Aircraft/Westover AFB	3-148
3.7.1 System Checkout at Westover AFB—J0V1-B (27) Mohawk Aircraft	3-148
3.7.2 System Checkout—UH1-D (89) Aircraft	3-153
3.8 RFI Checkout at GAEC—28 Feb 68 to 3 Mar 68	3-154
3.9 Compass Swing	3-154
3.9.1 UH-1D (89) Aircraft—System 2	3-154
3.9.2 J0V1-B (27) Aircraft—System 1	3-159
3.10 Wind Calibrate Mod (WCM)	3-159
3.10.1 Determination of Wind Data From Groundspeed Measurement	3-159
3.10.2 True Airspeed Variation Measurement	3-162
3.10.3 Measurement Parameter Study	3-163
3.10.4 Equipment Configuration	3-163
3.10.5 System Operation in Wind Calibration Mode	3-165
3.10.6 Sensitivity of the Wind Calibrate Mode Solution for Wind Vector to Measurement Errors and Course Geometry	3-165
3.11 Field Testing/System 1	3-180
3.11.1 Equipment Problems	3-180
3.11.2 Corrective Design Problems	3-181
3.11.3 J0V1-B Flights/Day-by-Day	3-181
3.11.4 Second Field Test Series	3-203
3.12 Field Test—System 2	3-206
3.12.1 Navigator Check Flight	3-206
3.12.2 Flight 22 Mar 68	3-207
3.12.3 Flights 23 Mar 68/24 Mar 68	3-209
3.12.4 Aberdeen Flight	3-212
3.12.5 Second System (Figures 3-95 through 3-100)	3-213
3.12.6 Second System Checkout	3-217
3.13 Documentation	3-233
4—Maintenance	4-1
4.1 Scope	4-1
4.2 Maintenance Concepts	4-1
4.3 Operational and Maintenance Manuals	4-2
4.4 Ground Support Equipment	4-5
4.5 Spare Parts	4-6
4.6 Repair Parts	4-6
4.7 Training Courses	4-6
4.8 Predeployment Considerations	4-6
5—Equipment and System Analysis	5-1
5.1 Scope	5-1

CONTENTS—Continued

Section		Page
5.2	System Human Factors and Safety Study	5-1
5.2.1	Purpose	5-1
5.2.2	Scope	5-1
5.2.3	Implementation	5-1
5.2.4	Product Safety Evaluation	5-2
5.2.5	Safety Recommendations	5-2
5.2.6	Human Factors Evaluation	5-2
5.3	Human Factors Plotter Study	5-3
5.4	Detector—Converter Transient Response Studies	5-3

ILLUSTRATIONS

Figure		Page
Frontispiece	AMPD-224 Phase IV System (Mounted in Fuel Pods) on J0V1-B Aircraft	ix
1-1.	AMPD-224 Orientation on OV-1 Aircraft	1-3
1-2.	Functional Organization of AMPD-224	1-4
1-3.	AMPD-224 System Function	1-5
2-1.	Filter Box Unit 117	2-6
2-2.	TAS Transmitter No. 1 With Pitot Tube	2-8
2-3.	TAS Transmitter No. 2 Without Pitot Tube	2-9
2-4.	Self-Destruct	2-12
2-5.	AMPD-224 Aircraft Ground and Signal Interfaces with Isolation Amplifiers	2-14
2-6.	TMG Display Modification—VSI	2-18
2-7.	AMPD-224 Phase IV Detector Logarithmic Output	2-31
2-8.	Log-Amp Detector and Analyzer Alarm Ratio Error vs Background Nuclei Count	2-32
2-9.	Modification No. 1	2-37
2-10.	Level Detecting Circuit Before and After Change	2-39
2-11.	Modification No. 4/V Detector Before and After Change	2-40
2-12.	Level Detector Circuit Before and After Change	2-42
2-13.	Feedback Motor Drive Module Circuit Before and After Change	2-43
2-14.	AMPD-224 System/Functional Block Diagram	2-45
3-1.	PERT Network Part 1/Project 224	3-3
3-2.	PERT Network Part 2/Project 224	3-5
3-3.	Pod 1 Center Section and Beam	3-26
3-4.	Pod 2 Center Section and Beam	3-27
3-5.	Pod 2 Center Section (Antenna Compartment)	3-28
3-6.	Pod 2 Center Section (Antenna Compartment and Cable Trough)	3-29
3-7.	Pod 2 Forward End Section	3-30
3-8.	Pod 2 Aft Beam Sections With Equipment Shock Mounts Installed	3-31
3-9.	Pod 2 Forward Beam Section With Equipment Mounting Brackets Installed	3-32
3-10.	Pod 1 Weight and Center of Gravity Determination (View Right Side)	3-33
3-11.	Pod 2 Weight and Center of Gravity Determination End Sections Removed (View Right Side)	3-34

ILLUSTRATIONS—Continued

Figure		Page
3-12.	Pod 1 Weight and Center of Gravity Determination (View Left Side)	3-35
3-13.	Pod 2 Weight and Center of Gravity Determination	3-36
3-14.	Pod 1 Weight and Center of Gravity Determination End Sections Removed (View Right Side)	3-37
3-15.	Pod 2 Weight and Center of Gravity Determination End Section Removed (View Left Side)	3-38
3-16.	Pod 1 Weight and Center of Gravity Determination End Section Removed (View Left Side)	3-39
3-17.	Detector Assembly	3-43
3-18.	Map Coder	3-69
3-19.	Power Distribution Block Diagram	3-103
3-20.	A-C Inverter Control Circuit	3-104
3-21.	Power Panel Circuitry	3-105
3-22.	Pod 1 Forward Center Section Wiring (End View)	3-112
3-23.	Pod 2 Tail Section—Magnetic Compass and Mounting Bracket	3-113
3-24.	Pod 2 Aft Beam Section Wiring (View top Left)	3-114
3-25.	Pod 2 Aft Beam Section Wiring (View Left Side)	3-115
3-26.	Pod 2 Center Section and Forward Beam Wiring (View Left Side)	3-116
3-27.	Pod 1 Forward Beam Wiring (View Left Side)	3-117
3-28.	Pod 2 Aft Beam Wiring (View Top Right)	3-118
3-29.	Pod 2 Aft Beam Wiring (View Right Side)	3-119
3-30.	Pod 2 Aft Section (View Forward)	3-120
3-31.	Pod 1 Center Section Wiring (View Forward)	3-121
3-32.	Pod 1 Forward Beam Wiring (View Top Right Forward End)	3-122
3-33.	Pod 1 Aft End Section (View Forward)	3-123
3-34.	Pod 1 Forward Beam Wiring (View Top Right Middle Section)	3-124
3-35.	Pod 1 Forward Beam Wiring (View Bottom Left)	3-125
3-36.	Pod 1 Center Sections Wiring	3-126
3-37.	Pod 1 Aft Beam and Center Section Wiring (View Left Center)	3-127
3-38.	Pod 1 Forward End Section Wiring (View Aft End)	3-128
3-39.	Pod 2 Forward End Section Wiring (View Aft End)	3-129
3-40.	Pod 2 Forward Beam and Forward End of Center Section Wiring (View Right Side)	3-130
3-41.	Pod 2 Forward Beam and Forward End of Center Section Wiring (View Left Side)	3-131
3-42.	Pod 2 Aft Beam and Aft End of Center Section Wiring (View Left Side)	3-132
3-43.	Pod 2 Aft Beam and Aft End of Center Section Wiring (View Aft Center)	3-133
3-44.	Pod 1 Aft Beam Wiring (View Forward End Right Bottom)	3-134
3-45.	Pod 2 Aft Beam and Aft End of Center Section Wiring (View Right Aft)	3-135
3-46.	Pod 1 Center Section Aft End Wiring (View Right Center Bottom)	3-136
3-47.	Pod 1 Center Section Aft End Wiring (View Left Center Bottom)	3-137
3-48.	Laboratory Facilities—Pod 2 and Cockpit Equipment Checkout	3-138
3-49.	Navigation Set—Testing Facilities	3-139
3-50.	Pod 1 Equipment Checkout	3-140
3-51.	Power Panel	3-143
3-52.	AMPD System Cockpit Display	3-144
3-53.	Plotter Memory Computer and Cockput Junction Box	3-145
3-54.	Analyzer	3-146
3-55.	OV-1 Baggage Compartment	3-147

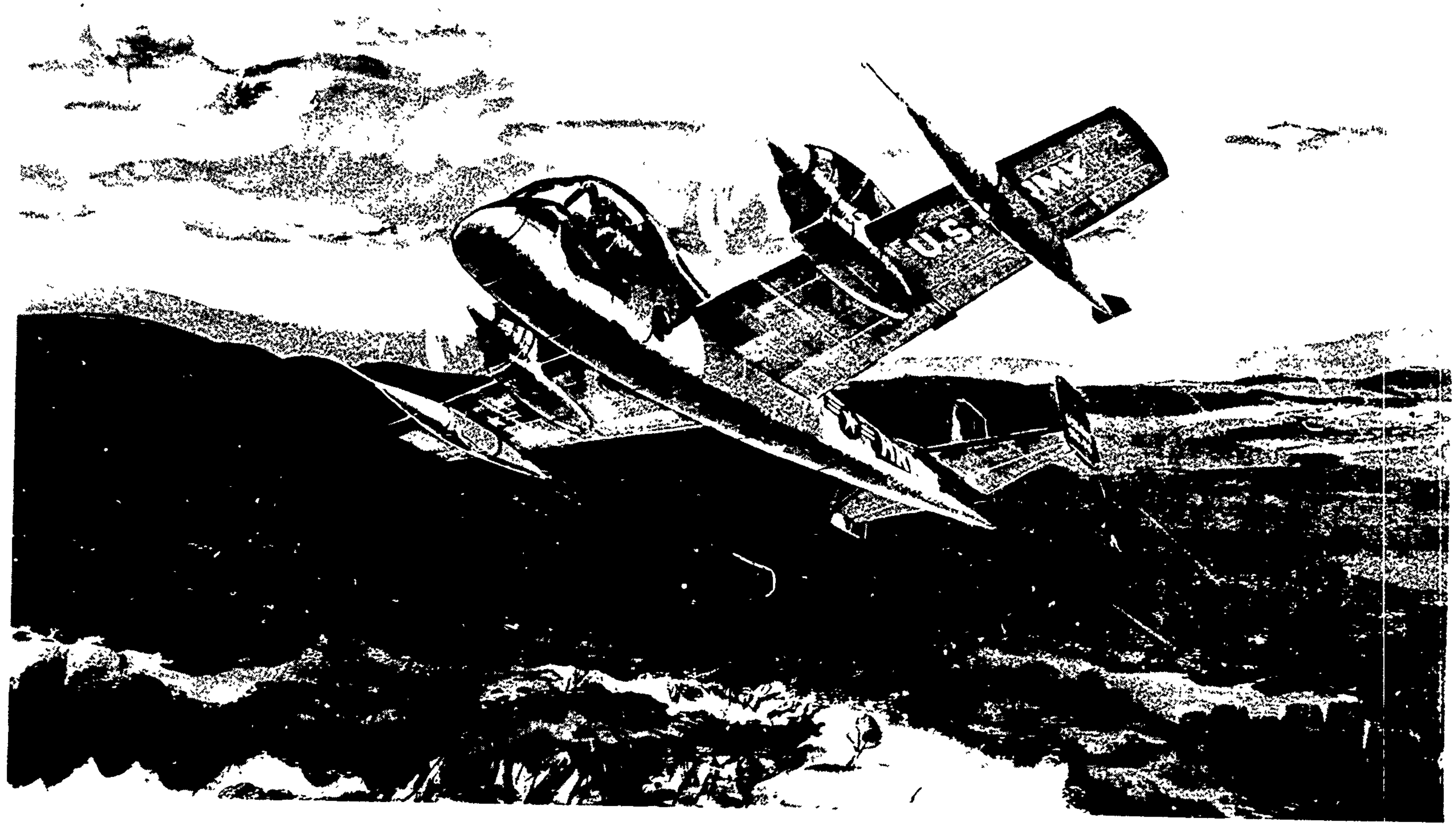
Figure		Page
3-56.	Control Indicator 336 Calibration Check of Present Position Readout	3-150
3-57.	Problem 3/1	3-151
3-58.	Vector Diagram for Groundspeed, True Airspeed, and Wind	3-164
3-59.	True Airspeed Variation Measurement	3-164
3-60.	Wind Calibration Mode Equipment Configuration	3-166
3-61.	Course Class 1 Vector Diagram	3-168
3-62.	Error Coefficients for Error in VG1 Magnitude	3-169
3-63.	Error Coefficients for Error in VG2 or VG3 Magnitudes	3-170
3-64.	Error Coefficients for Error in Ground Track Angle AG1	3-171
3-65.	Error Coefficients for Error in Ground Track Angles AG2 or AG3	3-172
3-66.	Error Coefficients for Error in ΔVA2 or ΔVA3 Magnitudes	3-173
3-67.	Course Class 2 Vector Diagram	3-174
3-68.	Error Coefficients for Error in VG1 Magnitude	3-175
3-69.	Error Coefficients for Error in VG2 and VG3 Magnitudes	3-176
3-70.	Coefficients for Error in Ground Track Angle AG1	3-177
3-71.	Coefficients for Error for Ground Track Angles AG2 and AG3	3-178
3-72.	Coefficients for Error in ΔVA2 or ΔVA3 Magnitudes	3-179
3-73.	Flight 4—J0V1-B (27)	3-184
3-74.	Flight 5—J0V1-B (27)	3-185
3-75.	Flight 6—J0V1-B (27)	3-187
3-76.	Flight 7—J0V1-B (27)	3-189
3-77.	Flight 8—J0V1-B (27)	3-190
3-78.	Flight 8—J0V1-B (27) (MAP)	3-191
3-79.	Flight 9—J0V1-B (27) Navigation Points	3-192
3-80.	Flight 9—J0V1-B (27)	3-193
3-81.	Flight 10—J0V1-B (27)	3-194
3-82.	Flight 10—J0V1-B (27)	3-195
3-83.	Flight 10—J0V1-B (27)	3-196
3-84.	Flight 10—J0V1-B (27)	3-197
3-85.	Flight 11—J0V1-B (27)	3-198
3-86.	Flight 11—J0V1-B (27)	3-199
3-87.	Flight 12—J0V1-B (27)	3-200
3-88.	Flight 12—J0V1-B (27)	3-201
3-89.	Tests 501 through 508 UH1D (89)	3-208
3-90.	Test 530 UH1-D (89)	3-210
3-91.	Test 529 UH1-D (89)	3-211
3-92.	Navigation Flight—UH1-D (89)	3-214
3-93.	Plotted Alarm Signals—UH1-D (89)	3-215
3-94.	Flight—Plotted from Printout UH1-D (89)	3-216
3-95.	E/W Control Indicator (Navigator) PP Calibration	3-220
3-96.	N/S Control Indicator (Navigator) PP Calibration Check J0V1-B (33)	3-221
3-97.	Preflight Test Map 1—J0V1-B (33)	3-222
3-98.	Preflight Test Map 2—J0V1-B (33)	3-223
3-99.	Preflight Test Map 3—J0V1-B (33)	3-224
3-100.	Preflight Test Map 4—J0V1-B (33)	3-225
3-101.	Preflight Test Map 3—J0V1-B (33)	3-226
3-102.	Preflight Test Map 4—J0V1-B (33)	3-227
3-103.	Sample Flight Plan	3-230
3-104.	Test 506—J0V1-B (33) Map	3-231
3-105.	Test 506—J0V1-B (33)	3-232

ILLUSTRATIONS--Continued

Figure		Page
4-1.	Maintenance Van Layout	4-3
5-1.	Total Plotter/Sensor Error for Different Map Scales	5-30
5-2.	Typical Converter and Detector Response Characteristics	5-41
5-3.	Converter and Detector Block Diagram	5-42
5-4.	Transient Responses	5-43
5-5.	Input Signal Pulse Widths for TDL Detector Only	5-44
5-6.	Distance Traveled vs Time	5-45
5-7.	Transient Responses for Case 1	5-46
5-8.	Input Signal Pulse Widths for TDL	5-47
5-9.	Transient Responses Case 1-TC Reduced by One-Half	5-48
5-10.	Input Signal Pulse Widths for TDL-TL Reduced by One-Half	5-49
5-11.	Transient Responses—Case 2	5-50
5-12.	Input Signal Pulse Widths for TDL—Case 2	5-51
5-13.	Detector with Blocks Step Response to CN	5-56
5-14.	Detector Without Blocks Step Response to CN	5-57
5-15.	Detector—Converter Step Response to CN	5-58
5-16.	Detector—Converter Block Diagram	5-59
5-17.	Basic Computer Program Listing	5-60
5-18.	Measured and Calculated Step Response—Detectors	5-61
5-19.	Measured and Calculated Step Response—Detectors and Converters	5-62
5-20.	Calculated Pulse Response Data for Detectors	5-63
5-21.	Calculated Pulse Response Data for Detectors and Converters	5-64
5-22.	Effect of Tube Diameter	5-69
5-23.	Effect of Valve Slot Size	5-70
5-24.	Effect of Input Tubing Length with 3-Inch Wick Humidifier	5-71
5-25.	Effect of Input Tubing Length	5-72
5-26.	Detector Response	5-73
5-27.	Typical Detector Response	5-76

TABLES

Table		Page
2-1.	Calibration Data for AMPD-224 Logarithmic Detector Output	2-30
3-1.	Weight Estimate/Pod 1 Phase IV	3-2
3-2.	Weight Estimate/Pod 2 Phase IV	3-7
3-3.	Aircraft Units	3-8
3-4.	Pod 1 Units	3-8
3-5.	Pod 2 Units	3-9
3-6.	Control and Display Functions/Operator Panel	3-10
3-7.	*Moisture-Vapor Transmission Rates (MVTR) of Organic Coatings (GR-MIL/100 SQ IN. -24 HR)	3-19
3-8.	*Useful Temperature Range	3-20
3-9.	**Humidity vs Insulation Resistance	3-20
3-10.	*Insulation Resistance (MEG)—TEMP Cycling at 95 Percent RH	3-21
3-11.	**Resistance of Coatings to Micro-Organisms	3-21
3-12.	Deliverable Voltages	3-108
3-13.	VSI Digital Readout Data	3-152
3-14.	AMPD-224 Effect on Aircraft Gear (Analyzer Source)	3-155
3-15.	AMPD-224 Effect on Aircraft Gear (Recorder Source)	3-156
3-16.	Aircraft Transmitting Gear Effect on AMPD-224 Gear	3-158
3-17.	Documentation Listing	3-233



Frontispiece. AMPD-224 Phase IV System (Mounted in Fuel Pods) on J0V1-B Aircraft

ABSTRACT

Two aircraft mounted personnel detector systems were designed, fabricated, checked out, installed on military aircraft and field tested. The systems were demonstrated to be capable of meeting the design criteria of detecting airborne effluents and predicting their locations.

Ground support equipment, spare and repair parts, and operational and maintenance manuals necessary for field and operational support were developed and supplied.

The systems developed on the Phase IV effort were essentially a refined and repackaged version of the Phase II system.

Section 1

INTRODUCTION

1.1 PURPOSE OF THE REPORT

The purpose of this report is to delineate the activities, the progress, and the results by the General Electric Company on Phase IV of the Aircraft Mounted Personnel Detector, Chemical (AMPD) 224 program. This effort was funded by the U. S. Army Limited War Laboratory, Aberdeen Proving Grounds, Aberdeen, Maryland, under Contract DA18-001-AMC-983(X).

1.2 PROGRAM SUMMARY

The General Electric Company's Ordnance Systems (OS) (previously Ordnance Department) had the responsibility for the equipment and system design, fabrication, aircraft installation, and checkout of two aircraft mounted personnel detectors, associated spare and repair parts, and ground test equipment. The systems are essentially refined and repackaged versions of the C-47 Phase II system. One system was mounted on a JOV-1B Mohawk aircraft (592627). The other system was mounted on a UH-1D helicopter, checked out, and remounted on a second JOV-1B Mohawk (592633). Associated documentation was also generated and delivered as a portion of the contract.

1.3 CONTENT OF THE REPORT/VOLUMES 1 AND 2

Volume 1 of the report contains the definition of the configuration of the AMPD, Phase IV, at the start of system design and fabrication phase. This definition is followed by a discussion of the several changes and modifications made throughout this period. The final configuration as of 31 December 1968 is essentially that of the Phase II, C-47 system as delineated in Aircraft Mounted Personnel Detector-Chemical (U)-Phase II Report, with small functional changes as defined in paragraph 2.1 and several program and equipment changes as defined in paragraph 2.2 of this report. Volume 1 is issued in a single binder.

The specific program activities are discussed in paragraph 3.0, which is divided into the various design function by equipments, system fabrication, test, aircraft installation and checkout, and field testing of the two systems at various locations. Documentation covering the final design and configuration is also listed.

The maintenance concept developed for field and depot support is implemented by the Operational and Maintenance Manual, GEK 5019. Spare parts, repair parts, ground support equipment, and training courses are discussed in paragraph 4.0 of this report. Section 5 contains various equipment and system equipment analyses of the 224 AMPD system.

Volume 2 (Appendices A through G) contains detailed information on systems test, system specifications, and pod handling. Volume 2 is issued as Parts 1 and 2 in separate binders.

1.4 AMPD EQUIPMENT DESCRIPTION

The 224 AMPD is composed of components, subsystems, and subassemblies produced by a number of different manufacturers. The various items of system equipment are arranged in three major groups; units mounted in the aircraft itself; units mounted in Pod No. 1 (suspended from the left wing of the aircraft), and units mounted in Pod No. 2 (suspended from the right wing of the aircraft). Figure 1-1 identifies, by system unit designation number and nomenclature, the units contained in each of the three groups. The system electrical cabling extending from the pod location on the undersize of each wing to the system junction box in the aircraft fuselage; the system cabling inside the aircraft fuselage; the system junction box; the cockpit junction box, and the brackets for mounting system units in the aircraft cockpit are permanently installed at the aircraft factory. The balance of the units of which the system is composed are removable in the field for replacement purposes.

The relationship of the various components in the AMPD system is shown in figure 1-2 in block diagram form.

The 224 AMPD senses the chemical effluents of man and his associated equipment as these effluents are dispersed through the atmosphere under the influence of meterological conditions. The system provides an analysis of the effluents, and displays the results of the analysis in terms of the calculated geographic location of the source of the effluents. The various functions of the system are performed by chemical detection, navigation, meteorological sensing, data handling, display, and control equipments. The detection process employs sensors to measure the number of condensation nuclei in an atmospheric sample. Wind is the prime mover of effluents in the atmospheric sample.

1.5 AMPD FUNCTION

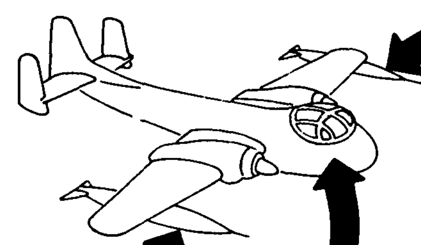
Following is an overall look at total 224 AMPD system function (see figure 1-3). A source of CN or convertibles is released into the atmosphere and diffused by the wind in a predictable manner. The resultant plume (shown two-dimensionally in figure 1-3) is carried downwind and fans out symmetrically about the wind vector. Given a constant wind and constant meteorological conditions, this pattern will hold waiting for the 224 AMPD system to fly through it.

The aircraft will fly a grid pattern in the surveillance area as nearly orthogonal as possible to the wind vector. Each leg or pass will be upwind at least 1500 meters of the last pass. Considering the last pass only (figure 1-3), it can be seen that the aircraft has flown through the plume and will have made detections (either CN or convertible) for a distance, W, determined by multiplying the average velocity from the navigational subsystem by the time in plume calculated by the Mk XII Computer with inputs from the chemical subsystem.

The navigation subsystem calculates the wind velocity, V, and transmits it to the Data Handling Subsystem (DHSS). Concurrently, the meteorological subsystem measures the ambient air turbulence, T, and transmits it to the DHSS. The Mk XII Computer (P/O the DHSS) now has the information needed to calculate the location of the effluent source. The distance Y is calculated using the following equation:

$$Y = \frac{CVW^{2/3}}{T}$$

where C is a constant wnich has been set into the system.



POD NO. 2 UNITS	
SYS. UNIT DESIG. NO.	UNIT NAME
200	Computer Junction Box
201	Navigator Computer
202	Antenna
203	Doppler Junction Box
204	Receiver/Transmitter
205	Frequency Tracker
206	Amplifier, Electronic Control
207	Displacement Gyroscope
208	Compass Transmitter
209	Side Slip Sensor
210	True Air Speed Transmitter
211	Detector 1
212	Detector 2
213	Detector 3
215	Pitot Static Tube
216	Roll Frame
217	Thermostat, Forward
218	Connector, Bulkhead Mounted
219	Thermostat, Rear
220	Corona Converter
221	Assembly
223	Doppler Simulator Connector
224	Temperature Probe
225	Connector, Compass Transmitter

AIRCRAFT UNITS	
SYS. UNIT DESIG. NO.	UNIT NAME
1A1	Tactical Display Panel
1A2	System Test Panel
1A3	Digital Control Panel
1A4	Cockpit Junction Box
3	Analyzer
4	Compass Controller
6	Control Indicator
7	Altitude Indicator
8	Velocity Steering Indicator
9	Power Panel
11	Plotter Display
12	Plotter Memory Converter
13	System Junction Box
15	Display Power Supply

POD NO. 2 UNITS	
SYS. UNIT DESIG. NO.	UNIT NAME
100	Metro Electronics
101	Connector, MRI Temperature Sensor
102	DRO Power Supply
103	Computer Program Unit
104	Computer Memory Unit
105	Recorder
106	S/D Converter
107	Multiplexer
108	RC-95 Power Supply
109	RC-95 D/A Converter
110	RC-95 D/A Converter
111	RC-95 A/D Converter
112	Fan 1
113	Fan 2
114	Air Temperature Sensor
116	Turbulence Sensor
117	Filter Box
118	±15v Power Supply
119	+15v Power Supply
120	+6v Power Supply
121	-6v Power Supply
122	Connector, Maintenance Power Panel
123	Fan 3
124	Fan 4
125	Fan 5
127	Thermostat
128	Capacitor Board

Figure 1-1. AMPD-224 Orientation in OV-1 Aircraft.

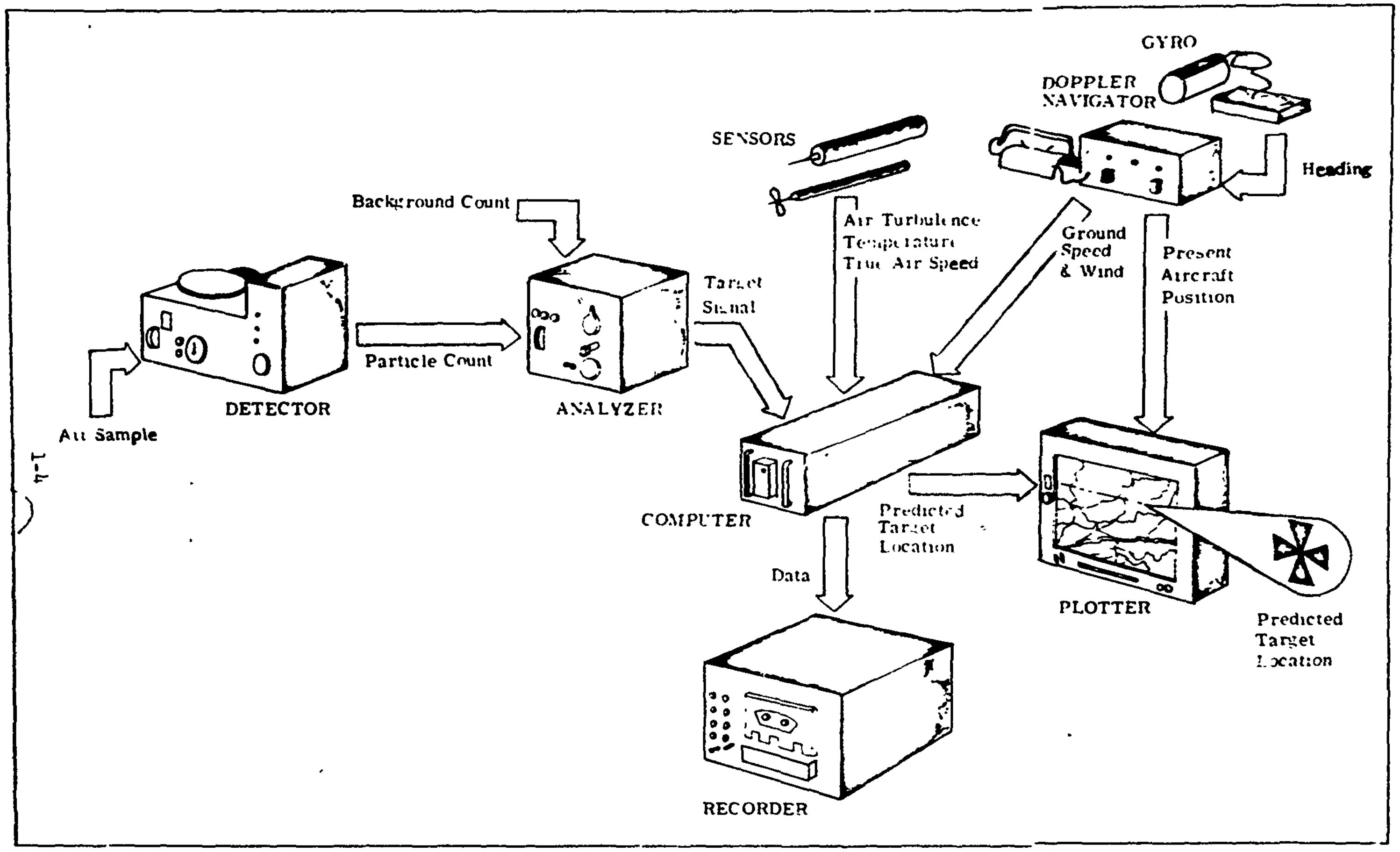


Figure 1-2. Functional Organization of AMPD-224.

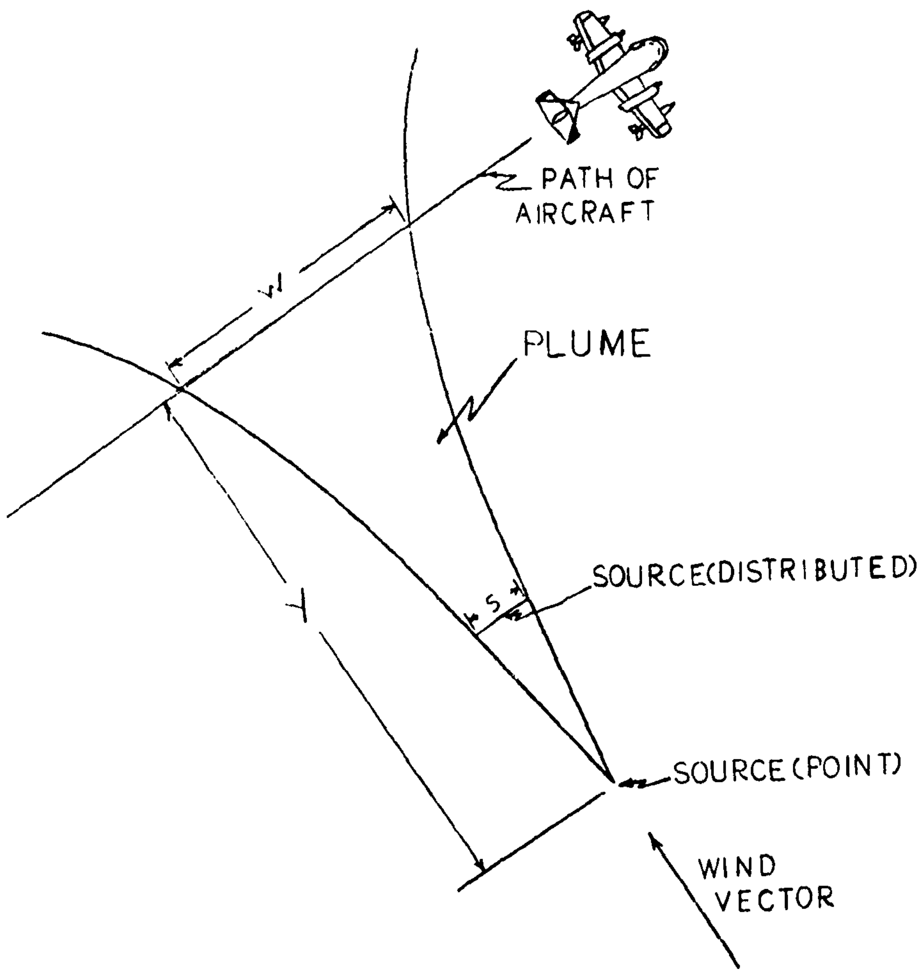


Figure 1-3. AMPD-224 System Function.

The distance Y is translated into map coordinates, and the plotter is commanded to mark the source location on the map, while the source location readout is commanded to display these coordinates. This source is a point source as indicated in figure 1-3.

A line or distributed source is also found by inserting a value S into the system. This value is an estimate of the length of the distributed source. The computer will calculate the midpoint of the source, command the plotter to plot this point, and the source location readout to display it. In this case, the computer solves the equation:

$$Y = \frac{CV\ (W^{2/3} - S^{2/3})}{T}$$

The S-guess plot is made first, then the point source plot. The Navigator also feeds position information to the plotter continuously, which the plotter plots to indicate the track of the aircraft.

The output of the 224 AMPD system, therefore, is a map with the aircraft track, the point source location, and the distributed source location marked on it. The two source locations are also displayed on the source location readout.

Section 2

SYSTEM CONFIGURATION

2.1 SYSTEM CONFIGURATION/1 JANUARY 1967

This section provides a summary of the AMPD 224 system configuration at the beginning of the Phase IV contract, and at the end of the contract; also included are the major design changes and modifications performed during the contract period.

Paragraph 2.1 is a definition of system configuration at the beginning of the contract in relationship to the Phase II, C-47 configuration. Paragraph 2.2 delineates the major design changes and modifications which occurred throughout the Phase IV effort. Paragraph 2.3 defines the final configuration in terms of the documentation package, the functional block diagrams and the modifications and changes denoted in paragraph 2.2.

The AMPD-224 Phase II System Configuration is defined in paragraph 3.0 of the Aircraft Mounted Personnel Detector-Chemical (U)—Phase II report. The Phase IV System performs the same function and is basically the same physical layout as the Phase II System, with some notable exceptions. It is a repackaged and refined version of the system developed in Phase II and refined in Phase III.

The major differences are as follows:

1. The Phase IV system utilizes one main power inverter mounted in the baggage compartment of the OV-1. This inverter supplies 115 volts, 400 cycles, 3-phase power to subsystems in the aircraft and the pods. The Phase II system has several inverters mounted in the pods.

2. The Phase II system has two Sol-A-Meters mounted on Pod 1 to measure solar radiation. It was hoped that this radiation could be related to local air turbulence. Because this relationship proved rather difficult to determine, Sol-A-Meters were not installed on the Phase IV system.

3. The Phase II digital multiplexer was built up from a type 2 Wire-Wrap plate, using relatively large plug-in modules. The Phase IV multiplexer is a repackaged unit using Honeywell modules and chassis resulting in a more compact (1.38 cubic-foot), lighter weight (24 pounds) unit.

4. The plotter provides a visual readout of source location plotted on a map. The Phase IV system contains in addition, a decimal readout of source location, which gives a more accurate indication of the location of the effluent source.

5. Accelerometers were added to the Phase II system to determine whether turbulence and acceleration could be related. Accelerometers were incorporated into the Phase IV design but were later removed when it was determined that turbulence could be directly measured more reliably by means of a turbulence sensor.

6. A present position indicator driven by the AN/ASN-64 Doppler Navigator is incorporated in the Phase II system as a cockpit display. Because the Phase IV control and display subsystem is located in the OV-1 cockpit, and includes present position on the control indicator, the present position repeater is not required.

7. The Phase IV system utilizes a stabilized antenna for more accurate doppler information during aircraft banks and turns, accomplished by using a roll frame to which the antenna is mounted, and driven by the AN/ASN-76 Miniature Reference System stabilizing signals. The Phase II System does not have this feature.

8. The Phase IV plotter had some added features not included in the Phase II unit. Some of these modifications were added during the Phase IV program and are discussed in paragraph 2.2.1. The initial changes included map overlap and continuous area of coverage (continuous MIN counting).

9. The C-47 system, with more console area available, included an analog recorder which the Phase IV system does not have. The OV-1 system, being more closely configured to a tactical application, does not require real time data output for analysis of the analog signals.

2.2 DESIGN CHANGES AND MODIFICATIONS

The Phase IV configuration at the beginning of the Phase IV program on 1 January 1967 was that defined in paragraph 2.1. As Ordnance Systems Engineering began the detailed development of the Phase IV System, the requirement for several changes became evident. Also, as the Phase II System began operation in the field, the need for further modifications was noted. Section 3 discusses the overall program with the changes noted in the appropriate design paragraphs. The major design changes and modifications are discussed in further detail as follows.

2.2.1 Plotter

2.2.1.1 Changes. Several changes were made in the plotter; isolation amplifiers were added to the navigation input; voltage spikes were minimized; some logic inversions were made in the Pod 1 interface; a pen-lift motion was added, and an Off-Map warning was incorporated.

The need for the isolation amplifiers became evident during Phase II tests (see paragraph 2.2.7). The other changes came about during Phase IV testing as problems were encountered, or the need for improving the display and information displayed became evident. The problems of voltage spikes and transcient sensitivity appeared early in the Phase IV system testing. The need for the pen-lift function and off-map indication became evident somewhat later.

2.2.1.2 Voltage Spikes And Transcient Sensitivity. The voltage spikes were being caused by the switching type power supply. Changes to the power supply and its RFI filter, and the removal of a jumper between chassis and power ground improved the situation. However, excessive current was flowing in the Pod 1 ground wires and apparently contributing to both the voltage spike and transcient problems. Further revision of the power supply to provide isolation between the grounds was necessary, and several logic signals were inverted (Off Course Command, 1/4 Inch Square Symbol, Rectangle Symbol, and Cover Open). Plotter operation was then considered acceptable. The logic inversions also required wiring changes in the multiplexer.

2.2.1.3 Pen-Lift And Off-Map. Two additional changes to the plotter became desirable; having the pen lift while moving to make a source location mark, and giving an off-map indication. It was found that the plotter's marking while moving to and from a source location caused a confusing and cluttered display if several source locations were in the same area. Also, were a source location outside of the displayed area, the plotter gave no indication that it had received such a plot. Both of these changes were incorporated into the plotters.

The plotter now executes a given offset command by lifting the pen from its present position, slews to the target position, draws the commanded symbol, lifts the pen, and returns to the updated present position where it resumes marking.

Issuing a no-mark command with the pen-lift modification would result in no presentation of information. Therefore, the requirement for a no-mark input to the plotter was eliminated, as was the requirement on the data handling equipment to generate the command.

Whenever any border is exceeded by an offset, the plotter now turns on the Off-Map light. The operator can then reset the light by pressing it. In this way, the operator is warned that a target can not be plotted. He can then take appropriate action to retrieve the target information.

2.2.2 Recorder And Magnetic Tape Printout

During February 1967, specifications and quote requests were sent to Kennedy for changes to the Phase IV recorder design, and also for the proposed ground support tape reader.

Several vendor contacts were made during March 1967. A trip was made to Kennedy to discuss and clarify Phase IV recorder requirements and to pinpoint long time delivery items affecting recorder delivery. Kennedy anticipated delays in receiving drive motors, and OS investigated the possibility of obtaining a DX rating for Kennedy on these items. Various changes in design were also requested.

In April 1967, a trip was made to Kennedy to discuss recorder design changes for improvement of vibration defects and to request Kennedy quote on costs and time delay involved.

In June 1967, the Phase IV Kennedy recorders were ordered, based on acceptable cost requote by Kennedy to ruggedize the Phase IV units and reduce their size.

In August, Kennedy forwarded an outline drawing of the Phase IV recorder which was approved by the pod design engineer; however, Kennedy was requested to strengthen the recorder door support with shear pins.

In October 1967, Kennedy Recorder delivery appeared to be slipping. Test magnetic tape was then due 15 November 1967; the recorder not before 25 November 1967.

A Kennedy test tape was received in November, 1967, and was run on several tape handlers at OS and at R & DC prior to acceptance of first ruggedized Kennedy recorder.

In December 1967 the Kennedy recorder was received after a successful read of a recorded tape at Kennedy and at GEOS.

During the first quarter of 1968, the following recorder effort took place:

A trip was made to Kennedy in January to define training and maintenance requirements for the incremental recorder. Additional discussions were held concerning improvements required in the recorder interface circuitry and recorder support hardware.

The Kennedy Recorder was connected and tapes produced were dumped on the 7044 with some parity errors (further debugging to be done at Westover).

In March, programing effort was initiated in TIPO (Schenectady) and in Pittsfield to provide data readout from the incremental tapes produced at the test site.

Subsequent to program checkout, the Kennedy recorder was installed and System No. 2 was shipped to Westover for aircraft installation. A program tape was made and subsequent multiplexer changes installed to allow the use of either Phase IV Kennedy recorder in System No. 2. (Recorder interfaces were different at that time.)

A magnetic tape was made and read satisfactorily on one 7044 (slow handler). Difficulty was experienced when reading on the 7044 with fast tape handlers. Test tapes are being made for the 7044 personnel to help isolate the problem.

In April, two recorder failures occurred. One Kennedy recorder was repaired by the vendor and underwent Pittsfield vibration test successfully. This recorder was later utilized on the UH-1 for final helicopter checkout. The second failed recorder was checked out in-house and eventually used in the OV-1.

In May, a tape was generated on the UH-1 flight and read on the 7044. Some magnetization problems are still encountered with the Kennedy tape recorders. Kennedy was requested to look at this problem at GEOS during June.

In June, a Kennedy Company field representative spent several days at GEOS investigating various tape recorder problems. Overheating was definitely established as a problem in the new recorders on the bench. Circuit adjustments were made as required in the record gap control, and an improved fan and ventilation plates will be installed in the near future. GEOS, Kennedy, and IBM personnel also spent considerable time investigating apparent specification incompatibilities between the Kennedy recorders and in-house IBM tape handlers. Changes were found to be required in the 7044 computer tape handlers (IBM 729) to allow consistent reading of Kennedy tapes on both low and high speed readers. Similarly, careful adjustment of Kennedy circuits needed to be maintained. A significant improvement in the quality of recorded and reproduced data was expected to result from this investigation.

Also in June, multiplexer changes were installed on both OV-1 aircraft to accommodate Kennedy recorder design changes in record gap circuits. The necessary changes were made to the program format on both OV-1 aircraft to agree with multiplexer changes. Ventilation plates were added to one OV-1 recorder.

In addition, a format for readout of C-47 magnetic tapes on the 7044 was produced, providing ability to read C-47 and OV-1 tapes at GEOS.

In July, corrective action was taken to allow more reliable readout of tapes. Changes were installed in the GEOS 7044 system 090 to allow Kennedy tapes to be read at high speed, and several tapes were successfully read in this manner. Heat runs were also in progress on the Kennedy recorders in an attempt to isolate any temperature design problems. High temperature magnetic tape was ordered for testing on the Kennedy recorder.

In August, magnetic tape readout facilities were investigated at Aberdeen/Edgewood. Preliminary requirements for utilizing the Aberdeen BRLESC computer and the Edgewood 225 computer were established, and recommendations made to the Program Manager.

Heat runs were completed on the Kennedy recorder and showed a recorder circuit tendency to malfunction at about 120 deg F. In the model tested, record gap control circuitry drifted badly at that temperature, but recovered when properly cooled. Other circuits in the flux check area were apparently subject to permanent damage at this temperature level. The bench recorder was returned to Kennedy for repair. Kennedy had stated that all recorders purchased by GEOS were of commercial design, not tested for 50 deg C operation. Purchasing has requested a quote from Kennedy, estimating costs of redesign and test to meet 55 deg C, 4-hour operation.

In September, the Edgewood 225 computer was programed to print out the OV-1 tapes, and was used several times successfully. Recommendations were submitted to keep the use of this computer to a minimum due to its very slow printout rate.

In the final quarter of 1968, little effort was expended on the Kennedy recorder. One unit failed and was shipped to Kennedy for repair.

All interface changes in the remaining recorder were made, making both Phase IV recorders identical.

More powerful fans were installed in both the Phase IV recorders to allow for better cooling and to reduce the possibility of failures due to overheat.

It was decided that no expenditures would be made at this time to redesign the recorders for operation at 55 deg C. During the last quarter of 1968, reliable operation was exhibited by the recorder in the OV-1 aircraft, and flight tapes were read out reliably on several machines at several locations.

One shipment of high temperature tape from U.S. Tape was delayed beyond the end of 1968, and was cancelled due to lack of funds to evaluate the tape when and if received.

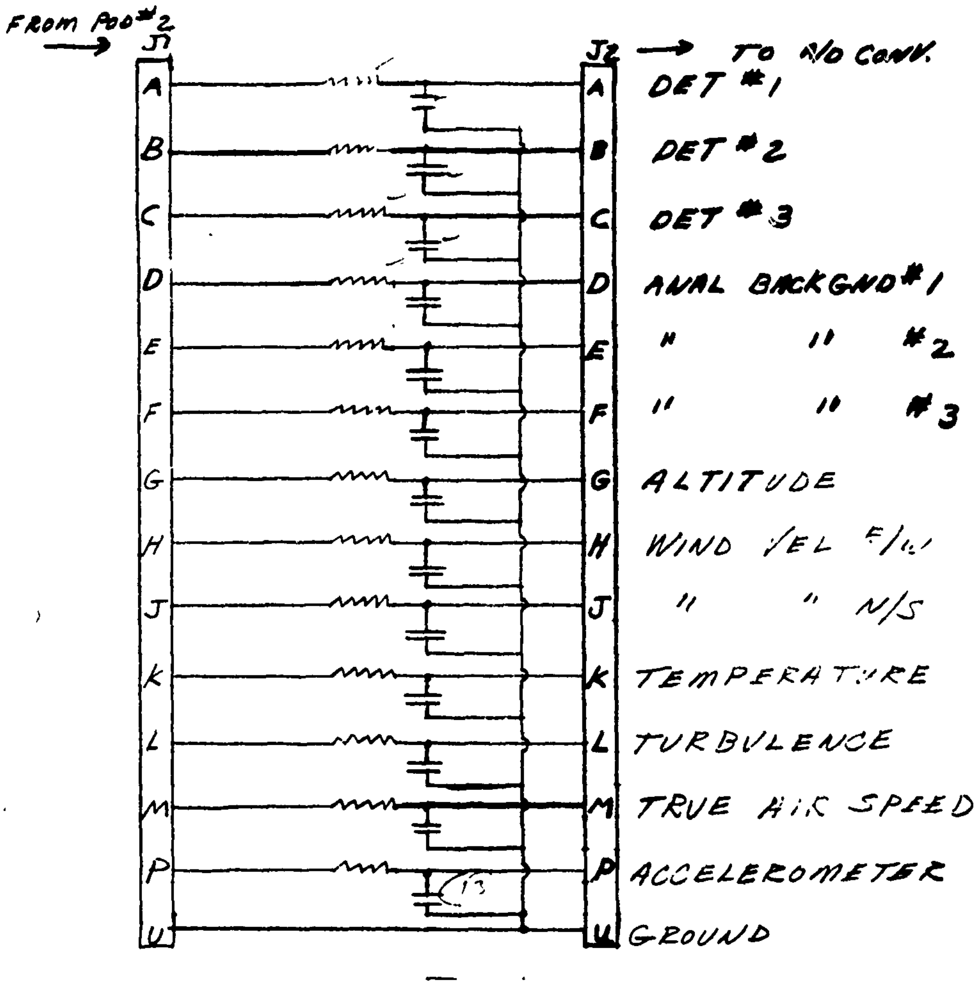
2.2.3 System Noise—Filter Box (Figure 2-1)

During the laboratory checkout of the AMPD-224 system, a number of noise problems were found. These problems, and the methods of corrections, follow:

1. The wind potentiometers were found to have noise riding on them which prevented proper analog-to-digital conversion in the A/D converter. The noise was:

   1.0 VPP at 100K PPS
   0.5 VPP at 4K PPS

   The 100 K PPS noise was being generated in the S/D converter, and put back onto the synchro input lines. This problem was eliminated by changing the capacitors on the S/D synchro lines from a line-to-line configuration to a line-to-ground configuration and adding a 100-ohm resistor in series with each synchro line. These components were installed in the S/D converter, and reduced the 100K PPS noise on the wind lines to 0.05 VPP.



NOTE. ALL RESISTORS 10K
ALL CAPACITORS .1μF

PIN "P" IS USED ONLY ON PHASE II SYSTEM

Figure 2-1. Filter Box Unit 117.

The 4K PPS noise was being generated back onto the 28-vdc power lines by the DRO power supply. The addition of a 500 μf capacitor across the 28-v terminals of the DRO power supply, reduced the 4K PPS noise on the wind lines to 0.02 VPP.

2. The background output lines in the analyzer were found to have 0.6 VPP at 8K PPS, which was being generated in the analyzer ± 15V power supply. The addition of an LC filter network on the output of the power supply module reduced this noise to 0.1 VPP at 8K PPS.

3. To ensure proper rejection of noise which could not easily be eliminated at its source, all the analog signal lines were filtered prior to A/D conversion. The filter consists of an RC combinations of 10K and 0.1 μf on each analog line. This provides 20dB attenuation at 10 kHz on all analog signals. See figure 2-1.

2.2.4 Accelerometer

The MRI turbulence measurement unit was found to be sensitive to vibration, and an accelerometer was proposed as a better way to sense turbulence. During May 1967, an accelerometer test package was developed at GEOS. The package consisted of an accelerometer, filters, and a breadboard amplifier. The accelerometers package was completed on 16 June 1967 and sent to R & DC for tests on the NU-8F aircraft. The test results were inconclusive, and R & DC was in favor of returning to the MRI turbulence measuring unit. On 2 August 1967 it was decided to cancel the accelerometer effort and use the MRI equipment in the system to measure turbulence.

2.2.5 Precise Wind Solution

The true air speed transmitters were calibrated to determine the existence of any hysteresis which would prevent the removal of TAS transmitter error with the addition of a differential synchro.

Two TAS transmitters were calibrated to determine the type and amount of error in the range of 50 to 250 knots airspeed.

2.2.5.1 Transmitter No. 1. The first TAS transmitter was mounted in System 1 and was calibrated with its pitot tube. True air speed was recorded from both the digital display panel and VSI groundspeed (wind set to zero). A water manometer was used to apply pitot pressure. Data was recorded going from 50 to 250 knots twice, and from 250 to 50 knots once.

2.2.5.2 Transmitter No. 2. This transmitter is the system spare and was calibrated without a pitot tube. True air speed was read on the VSI only.

The recorded TAS was compared to the calculated TAS for the corresponding pitot pressure, static pressure and temperature. The recorded TAS and error are plotted in figures 2-2 and 2-3 and the results are summarized as follows.

2.2.5.3 Results.

1. TRANSMITTER No. 1

   a. No hysteresis effect was shown measuring from 50 to 250 knots compared to measuring from 250 to 50 knots.

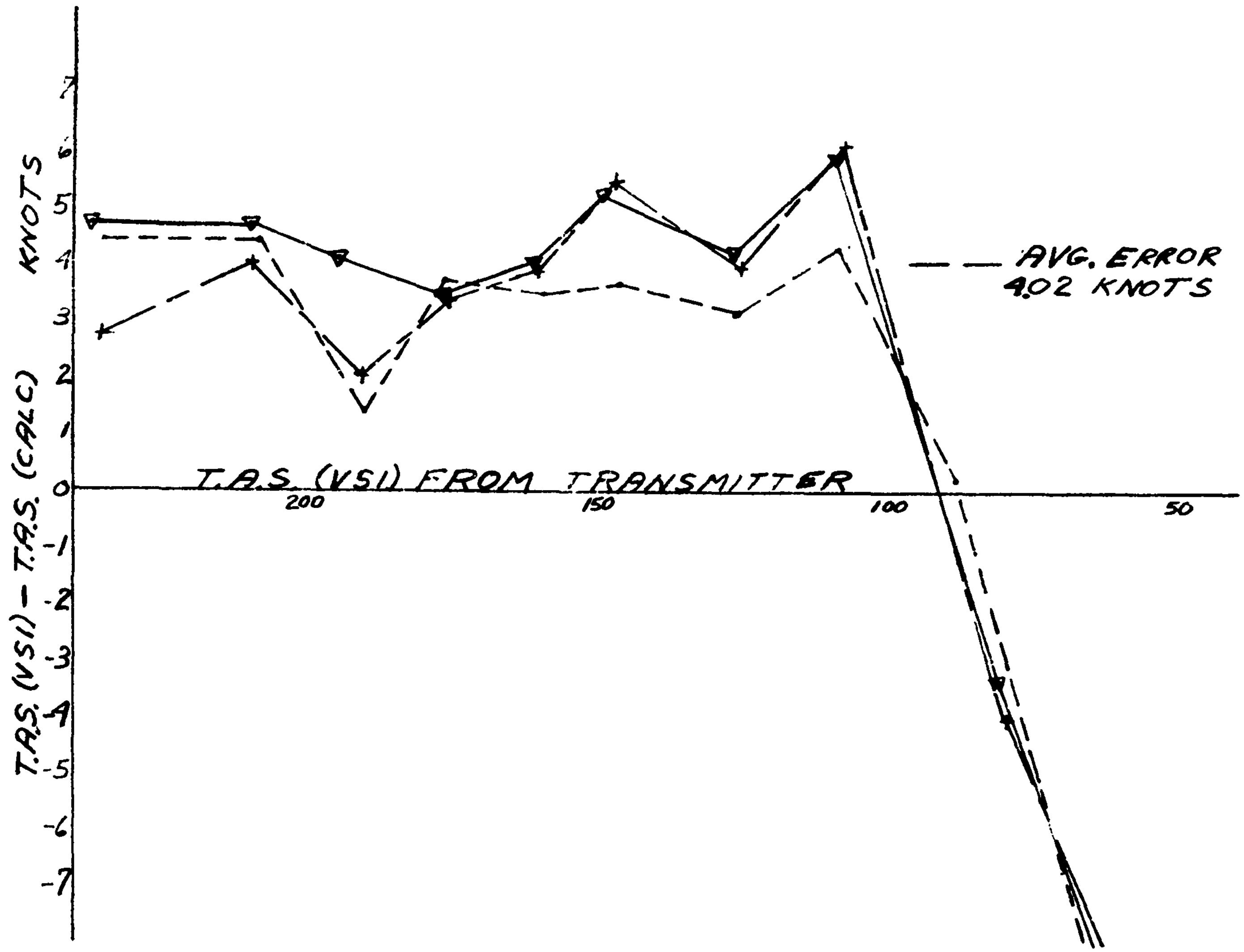


Figure 2-2. TAS Transmitter No. 1 With Pitot Tube.

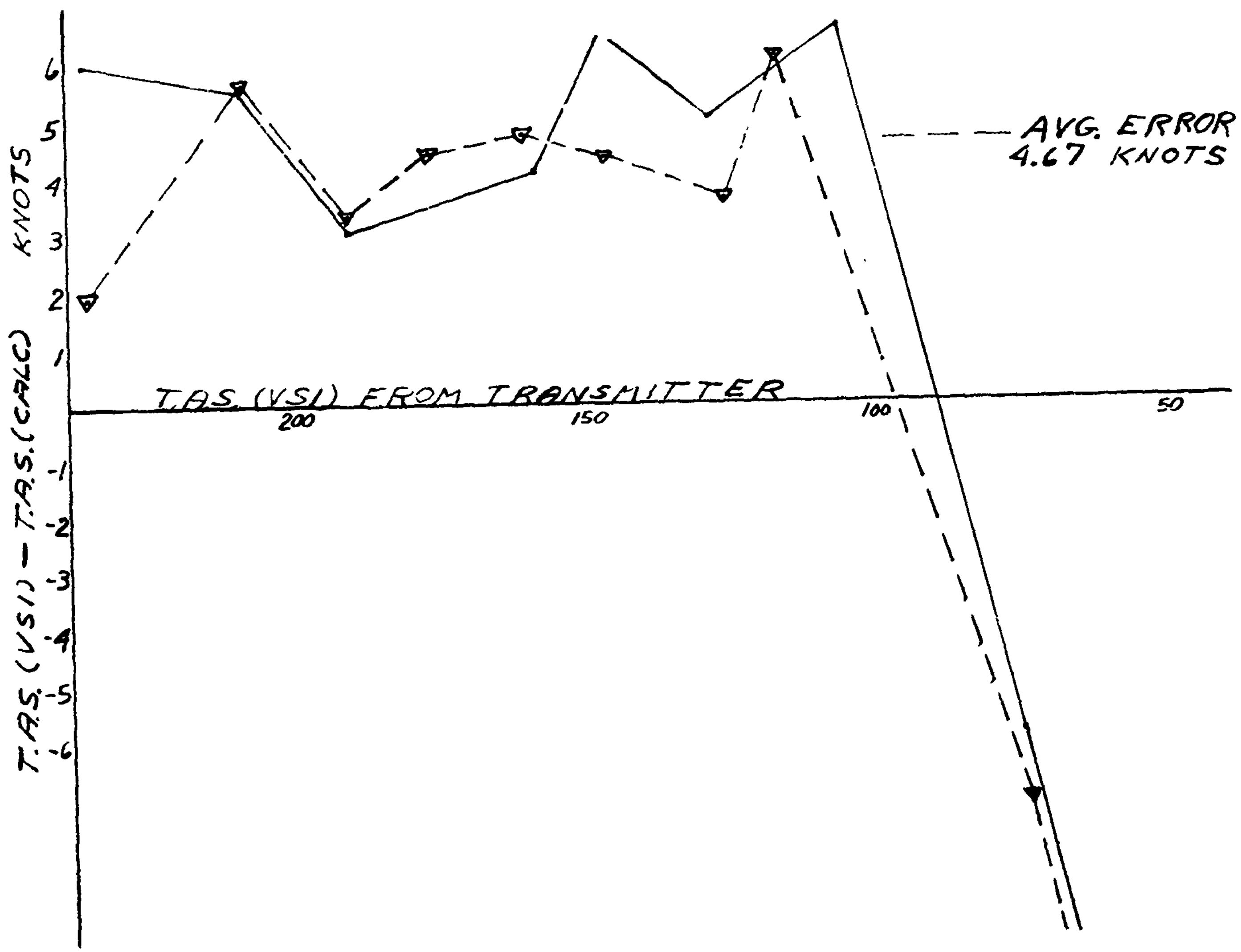


Figure 2-3. TAS Transmitter No. 2 Without Pitot Tube.

b. The TAS measured on the VSI agreed with that displayed on the digital display panel within +1 knot.

c. In the range of 100 to 250 knots, the error due to the TAS transmitter was fairly constant, averaging +4.02 knots above the calculated TAS. Below 100 knots, this error changed linearly to -18 knots at 50 knots airspeed.

2. TRANSMITTER No. 2

In the range of 100 to 250 knots, the TAS transmitter error was fairly constant, averaging +4.67 knots above the calculated TAS. Below 100 knots, this error changed linearly to -18 knots at 50 knots airspeed.

2.2.5.4 Conclusions. In the operating range of interest (100-200 knots) the TAS transmitters had a fairly constant average error of +4.35 knots.

To eliminate this error, a differential synchro was added in series with the input of the TAS transmitter. The synchro was mounted in Pod 2 just forward of the detectors, and its stator was wired to the TAS transmitter input and its rotor to the navigational computer. The synchro's rotor was clamped and the case was rotated from its zeroed position to cancel the error in the TAS transmitter.

2.2.5.4.1 Elimination Of The Wind Calibrate Mode. The need for a Wind Calibration Mode (WCM) was eliminated with the addition of a differential synchro in the input line to the True Airspeed Transmitter and a correction to the Side Slip Sensor angular position and the appropriate procedures to calculate the corrections. In the Wind Calibrate Mode, the cross track and along track wind error were calculated in the Mk XII Computer, and bias was provided to eliminate these wind errors. With the eliminations of WCM, the cross-track and along-track wind error was determined from flight data, and the errors were removed from the wind solution by adjusting the TAS differential synchro (along-track wind error) and the Side Slip Sensor (across-track wind error).

The flight data required to determine the appropriate adjustments to the differential synchro and the Side Slip Sensor was obtained by following a precise flight plan. The aircraft had to be flown at an altitude at which the average wind was constant to within one knot. Reciprocal headings were flown at the airpseed for which the calibration was desired, with the wind solution data being recorded digitally. Six courses were flown to give enough wind data for analysis.

The analysis* used the printout of the digitally recorded wind data to determine the average wind components for each course. These were combined to give average wind components for each direction of flight. True airspeed errors produced wind errors in the direction of flight, while yaw errors resulted in wind errors perpendicular to the direction of flight.

The difference in the wind component for receprocal heading courses along the aircraft track determined true airspeed error as follows:

$$\text{True airspeed Error} = \frac{\text{Difference of Wind Components Along Track}}{2}$$

* For a more detailed explanation of the data analysis, see section 5-7.4 of the GEK-5019 Manual.

Similarly, the across-track wind component difference determined the Slide-Slip Sensor error as follows:

$$\text{Side-slip sensor} = \frac{\text{Difference of Wind Components Across Track}}{2\ (\text{TAS})}$$

The resulting corrections were then made to the TAS differential synchro and the side-slip sensor, and the wind calibration was completed.

The elimination of WCM was significant to systems operation in two respects. First, the capacity of the Mk XII Computer was increased because the WCM calculations were no longer performed in the computer. Secondly, the need for a three-legged WCM flight prior to each mission was eliminated.

2.2.6 Self-Destruct

On 13 March 1967, the 224 AMPD System requirements were changed to include pod-mounting provision for jettisoning, and the necessary wiring and connectors for a destruct assembly. The destruct assembly itself was not required.

In defining the self-destruct requirement, the purpose of self-destruct was interpreted to be served by destroying the chemical subsystem elements in Pod 2. Though no self-destruct package could be found, figure 2-4 illustrates what was understood to be a typical self-destruct circuit.

Once armed, self-destruct would be accomplished by either activation of the pod eject command or by ground impact. GEOS provided extra wires in the pods and from the aircraft cockpit to the pods, which allow installation of the pilot's destruct panel in the aircraft and installation of the detonator assembly, impact switch, squib-activated battery, and destruct changes in the pods at a later date with minimum effort.

2.2.7 Ground Isolation Changes

A number of grounding problems found in the 224 AMPD system necessitated grounding changes.

A ground loop was found to exist from Pod 1 to Pod 2, through the TND-4 plotter. GEOS Circuits Engineering was requested to design a device which would effectively isolate the navigator ground from the plotter ground without affecting the navigator pulses which drive the plotter. This grounding problem was further investigated by measuring the signal characteristics of the navigator output, and obtaining the specification of the plotter input circuitry. The following additional information was then supplied to Circuits Engineering:

1. Navigator 1/100 km Pulse Characteristics:

$t_r < 20\ \mu$sec.		overshoot	= 0 v
		undershoot	= 0 v
$t_f < 20\ \mu$sec.		ripple	= 0 v
		droop	= 0 v

pulse width = 500 ± 50 μsec.

amplitude (no load) = 5.0 ± 0.2 volt

repetion rate = 350 pps maximum

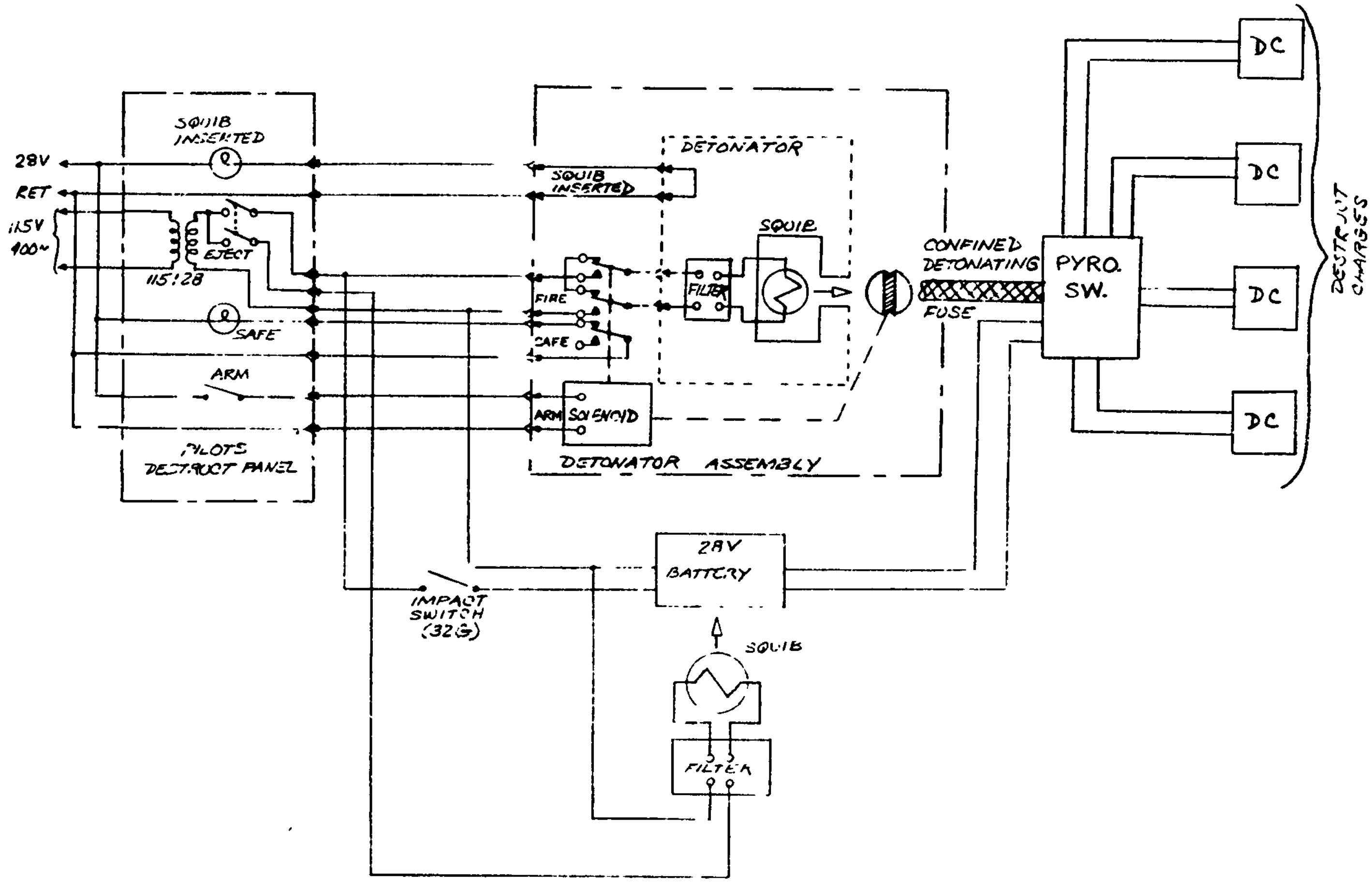


Figure 2-4. Self-Destruct.

2. Plotter Input Signal Characteristics:

Pulse width = 200 μsec and T = 550 μsec.
$T_r + T_f \leq 20$ μsec. (200-μsec pulse)
≤ 100 μsec. (550-μsec pulse)
Undershoot ≤ 1.0 volt
Overshoot: Not critical as long as maximum amplitude is 6.0 volts
Amplitude: $4.0 \leq A \leq 6.0$ volts
Input load = 1000 ohms
Ground reference: The signal source zero output must be -0.0 to +0.5 volt, with 4.0 ma coming from the plotter input.

A schematic of the navigator output circuit was also supplied. It was expected that to realize 1 volt of noise between the navigator ground and plotter ground, 20-dB isolation between the grounds would be required.

A meeting was held on 17 July, 1967 to further discuss Phase IV interface requirements of the TND-4 plotter. Discussion of the plotter/navigator isolation circuit was extensive. It was determined that the output from the navigator was not as expected. It was then decided that the circuit being prepared by GEOS Circuits Engineering was not as desirable as an operational amplifier circuit.

An operational amplifier was constructed by GEOS and tested by Loral. The amplifier was installed in the Phase II plotter and operation was satisfactory. Specification AMPD-11 was then written to include the isolation amplifiers in the Phase IV plotters. (A copy of AMPD-11 is included in this report as appendix D.) The installation of these isolation amplifiers eliminated the ground loop from Pod 1 to Pod 2 through the TND-4 plotter.

The detectors pumps were found to have a current surge (2.2 amps) at 10 Hz, which was causing adverse effect on the circuit power on the detectors. To correct this problem, separate power distribution was provided for detector pump and circuit power. As a further precaution, power ground and signal ground (instrument ground) were isolated in the detectors. These changes effectively isolated the current surges of the pump from the circuit power lines in the detectors.

It was desired to keep the detector signal ground (instrument ground) isolated from power ground until the detector output reached the A/D converter on Pod 1. This required that the power ground and signal ground on the analyzer be isolated. The analyzer ±15v power supply was changed to an isolated power supply. Thus, both the detector output and the analyzer background output signals were isolated from power ground until the signals reached the A/D converter on Pod 1 (see figure 2-5).

2.2.8 Detectors

Investigations to improve the sensitivity and reliability of the detectors were made and resulted in several modifications to the AMPD-224 detectors. The modifications included teflon coating of valve plates and rotary valves; incorporation of improved stainless steel wicks; addition of vacuum accumulators, and venting of the motor mount to provide for cooling. The electronics of the detectors were also changed to provide a longarithmic output (see para 2.2.13). Also some of the stainless steel vacuum lines failed due to acid, and were replaced by tygon tubing.

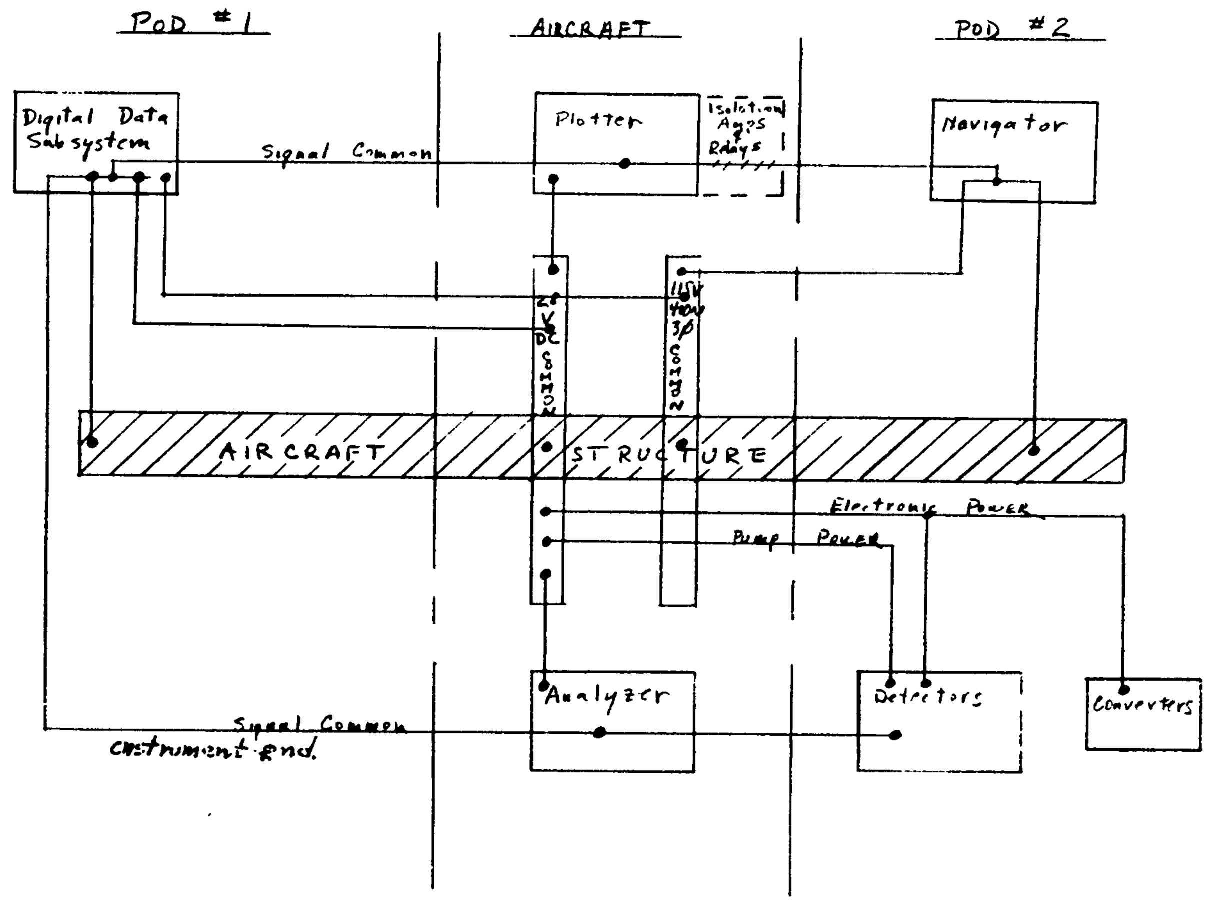


Figure 2-5. AMPD-224 Aircraft Ground and Signal Interfaces with Isolation Amplifiers.

One of the major problems was the selection of a suitable material for the surface of the rotary valves. Teflon (or a composite of Teflon and glass in various concentrations) appeared to be suitable because of low coefficient of friction, resistance to acid errosion, and surface quality.

On 9 February, GEOS representatives visited Chemplast, Inc., Wayne, New Jersey, to discuss potential solutions to the detector valve problems of wear and flaking. Chemplast was selected because they handled not only Teflon coatings, but also filled Teflon, tape, rod and tubing.

GEOS outlined the general problem and solicited recommendations as to materials, finishes, etc.

The general consensus was that most of the obvious alternatives had already been tried; however, there were three approaches which might work,

1. Coat the valve plate of the detector body with one of the new Teflon S coatings to a thickness of about 0.5 mil. Test the suitability of this coating, using Teflon-faced valves of 0-, 10-, 15- and 20- percent glass fill.

2. Coat the valve plate with a Teflon enamel and test it with valve facings of Teflon, Teflon S, and various percentages of glass-filled Teflon.

3. Test a hardened and highly polished valve against plate coatings of virgin Teflon, Teflon S, and Teflon enamel.

One valve plate with Chemplast was coated with Telfon S and sent to GEOS for evaluation. In the meantime, additional valve plates to be coated later with various other finishes were made at GEOS. In the event that a satisfactory solution was found, it was agreed that Chemplast would provide coating services for production parts.

A study was then made to determine if the 20-percent glass-filled TFE valve material was suited to the detector rotary valve application.

The valve used was the same design and material as valves W-1, W-2 and W-3 installed on the 10-Hz Phase IV detectors presently being used in Phase II.

The 10-Hz detector was prepared by cleaning the vacuum regulator, source and receiving optics, the expansion chamber, humidifier, and the rotary valve base surface. The rotary valve was lapped with a 240-grit sandpaper, and cleaned.

The test valve acquired 5 hours wear before the detector motor circuit fuse blew. This overload on the motor circuit was believed to be caused by an excess amount of acid in the system. The wick on the corona converter had been filled to saturation at regular intervals. This amount of acid seemed to lift the TFE coating on the detector valve seat at the radius of humidifier output and expansion chamber input. This situation created an additional load on the motor. Further investigation was needed in this area.

The test valve was transferred to unit S/N 011. With 13-1/2 hours on this unit, the problem of the overloaded motor circuit reoccurred.

This unit was placed in running order and continued to run until the valve study ended.

In conclusion, the 20-percent glass-filled TFE material seemed well suited for the detector rotary valve application in the absence of acid.

No excess flaking or leakage problem occurred in more than forty hours of testing. The TFE coating on the detector valve base plate in an extreme acid environment warranted further investigation.

To test various humidifier configurations, the following test setup was used: An AMPD-224 Phase IV detector was utilized with its rotary valve and drive assembly removed. A fitting was fastened to the humidifier outlet port on the detector valve block and a flow meter was placed in the inlet line to the detector. From the fitting on the valve block, the air sample was ducted to a bottle which housed a humidity sensor. An air pump was then connected on the outlet of the humidity sensor and provided the means of air movement. Air flow was adjusted to approximately 35 cc/sec through the humidifier. This rate is approximately 75 percent of the total 10 cps detector flow.

The parameters that were monitored were inlet humidity, ambient temperature, humidifier temperature, humidity sensor inlet temperature, and humidity sensor bridge output.

Humidifier wick materials tested included Dacron felt and porous stainless steel. The Dacron wicks were constructed by spacing the pieces of felt with aluminum plates, then placing this sandwich in a holder, which allowed changing the wick configuration and volume of felt being used so that the wicks properties could be maximized. The stainless steel wicks were tested in a number of porosities, such as 40-micron pore size as well as different configurations and volumes. A configuration using the porous stainless steel was finally chosen for use in the detectors.

The effect of adding an accumulator to the vacuum system of the detectors was tested in the following manner. The position of the rotary valve was noted and the drive gear was marked so that readings could be synchronized to the valve's position. Vacuum in the expansion chamber of the detector was measured using a pressure transducer and oscilloscope. The pressure wave on the oscilloscope was then noted.

The relative position of the drive gear with respect to the rotary valves position was then varied (4 gear teeth per datum point), done both with and without the accumulator. It was noted that without the accumulator, the wave shape varied with some dependence on the relative position of the gears. Using the accumulator, the wave shape was uniform and well-defined, with none of the unstability that was present without the accumulator. Accumulators were then added to all of the AMPD-224 detectors.

During laboratory testing, it was also found that the detectors were temperature sensitive. The major source of heat in the detectors is the motor. It was therefore decided that the motor mounts should be modified to provide venting such that a fan mounted in the beam of Pod 2 could force air up through and around the motors. This cooling has been incorporated into the detectors and system.

2.2.9 Converter Changes

As a result of the investigation conducted by R&DC into Corona Converter operation problems, the following changes were made in the AMPD-224 System.

1. Corona Points. The size of the corona points was reduced to 0.001 inch in diameter, and they were constructed to be easily installed and removed.

2. Converter Heaters. Provisions were made in the AMPD-224 System to supply 28 vdc to the corona converters, accomplished by mounting a heater push button and two heater current control potentiometers in the System Test Panel located in the cockpit. No heaters were actually installed in the converters; only provision for a future installation of heaters was made.

3. Converter Location. The location of the converters was changed from the pod beam to the pod front cover, done to minimize the converter inlet length. For more detailed information on this modification see para 3.3.1 (Pod Design).

4. Converter Inlet Tube Length. As a result of a boundary layer study conducted at R&DC, the converter inlet tube length was changed to 3/8 of an inch, and the end of the tube was beveled to prevent water from entering the converter (see para 3.3.1).

5. Temperature. With the converters mounted on the pod cover, the temperature difference between the detectors and converters became a problem because of its effect on converter sensitivity. Fans were installed under the detectors, and an air duct modification was made on the pod to bring outside air into the region of the detectors (see paras 3.3.1 and 2.2.8, Detector Changes).

2.2.10 TMG Display—VSI

The 224 AMPD System was modified, to eliminate control of the directional pointer on the VSI by the Wind Direction knob on the Control Indicator. Prior to this modification, the directional pointer was controlled by the Wind Direction knob on the Control Indicator when the Wind Set/Read switch on the VSI was in the set or read position, which presented a problem during flight, because whenever the wind was selected on the VSI, the directional pointer no longer indicated aircraft track or heading. Actually, in this mode, the position of the directional pointer held no significance whatsoever.

The wiring in the System Junction Box was modified so that the Track Made Good (TMG) would be displayed on the VSI whenever the Wind Set or Wind Read was selected (see figure 2-6 for modification).

2.2.11 Synchro Loading

It became evident (14 Aug 68) that the navigator's wind solution wasn't as accurate as was expected during ground test. It was found that with the Side-Slip Sensor visually zeroed, that the wind solution would consistently solve to one side or the other of true track. (The wind solution should fall along true track under the test conditions.) The wind solution could be made to fall on track by manually adjusting side slip or by jumping out the side-slip Sensor. The problem, therefore, appeared to be caused by either incorrect alignment of the side-slip sensor or some electrical effect caused by including the side-slip sensor in the system.

A study was then made to determine what the synchro signals being used in wind solution should be. A mathematical model of the synchro chain was obtained, and a computer program was used to calculate the desired values.

The synchro chain used in the wind solution is the compass transmitter, variation control differential, side slip and drift differentials, ending in the true heading and true track control transformers (see FBD 10). The characteristic impedences of these synchros are as follows:

1. Compass transmitter

$Zro = 54+j260$
$Zso = 16+j60$
$Zrs = 88+j22$

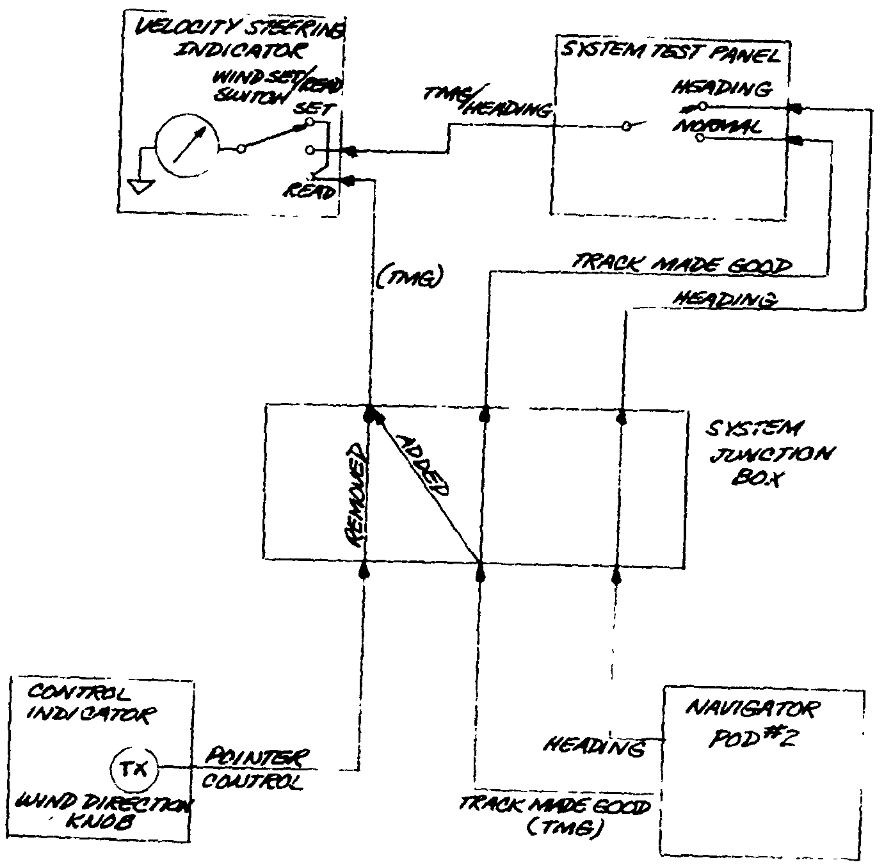


Figure 2-6. TMG Display Modification—VSI

2.	Variation, side-slip, and drift	Zro = 38+j122 Zso = 28+j114 Zrs = 47+j13
3.	True heading	Zro = 470+j1770 Zso = 81+j330 Zrs = 590+j190
4.	True track	Zro = 195+j760 Zso = 29+j124 Zrs = 240+j80

A number of problems were then computer-calculated representing several wiring configurations of the synchro chain; the results are shown in the computer printouts following.

Voltage and phase measurements on the system gave good correspondence with calculated values.

It was then found that the wind solution error could be minimized by either increasing the voltage received by the navigator computer amplifiers (true heading and true track synchro outputs), or by correcting for voltage phase shift. It was then decided that correcting for phase shift was the best and also the most convient method.

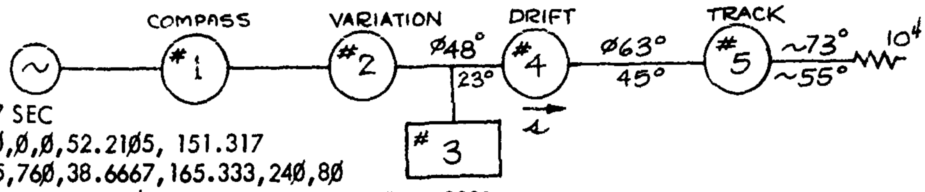
A capacitor bridge was then added across the output of the variation synchro, and the capacitance adjusted while monitoring the phase shift. The measurements indicated that 3-μfd capacitors gave nearly zero phase shift and the best wind solution. Computer calculations were then made to verify these results. The calculations indicated that 3.6-μfd capacitors would be best, which gives good correlation to the measurements. The following computer printout was obtained. (See following pages.)

The final fix was to permanently fasten 3-μfd capacitors to the true heading terminal points (9T, 12T, 15T) in the navigator computer junction box; 3.6-μfd capacitors would give the best results, but they are available only as long lead time items. However, no improvement in wind solution would be noticable over that with the 3-μfd capacitors (the residual errors being limited by the navigator computation).

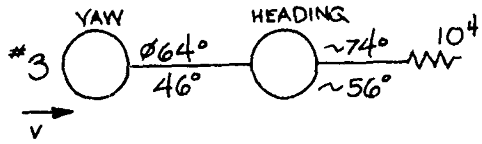
2.2.12 Turbulence Propellers

During flight tests conducted in Florida in March, 1968, there were repeated failures of turbulence sensor propellers. Failures consisted of the loss of one or more blades while the aircraft was in flight. The blades either broke off at the root or pulled out of the hub. All failures in Florida occurred in the Phase IV system mounted on the JOV-1B. One failure has previously occurred on the Phase II system installed on the C-47, andanother had occurred on an identical turbulence sensor used on the NU-8F as part of the breadboard system.

A series of tests was conducted in the Gas Dynamics Laboratory in Schenectady to determine the cause of failure. A turbulence sensor was mounted in a jet of air issuing at 190 ktfrom the outlet of a large air compressor.



RAN 12.17 SEC
4 DATA Ø,Ø,Ø,Ø,Ø,52.21Ø5, 151.317
6 DATA 1,195,76Ø,38.6667,165.333,24Ø,8Ø
5 DATA 2,37.3333,152.5Ø.6667,162.667,62.667,17.3333
RUN



FILE SIZE LIMIT

CNET** 16:43 ST FRI Ø9/Ø6/68

CASCADED NETWORKS

NO.	TYPE	IMPEDANCES						
1	1	54	26Ø	16	6Ø	88	22	
		T	46.7523	138.Ø31	8.75228	-61.9694	7.24772	121.969
2	2	37.3333	152	5Ø.6667	162.667	62.6667	17.3333	
		T	25.3755	1.39552	38.7Ø89	12.Ø625	11.9578	15Ø.6Ø4
3	Ø	Ø	Ø	Ø	Ø	52.21Ø5	151.317	
4	2	37.3333	152	5Ø.6667	162.667	62.6667	17.3333	
		T	25.3755	1.39552	38.7Ø89	12.Ø625	11.9578	15Ø.6Ø4
5	1	195	76Ø	38.6667	165.333	24Ø	8Ø	
		T	167.195	42Ø.973	1Ø.8616	-173.694	27.8Ø51	339.Ø27

SOURCE VOLTAGE IS 26 +J Ø
SOURCE IMPEDANCE IS Ø +J Ø
LOAD IMPEDANCE IS 1ØØØØ +J Ø

THEVENIN EQUIVALENT VOLTAGES AT OUTPUT

NO.	REAL	IMAG	MAGNITUDE	PHASE
Ø	26	Ø	26	Ø
1	11.8369	1.73366	11.9632	8.33236
2	9.8[illegible]9	4.45766	1Ø.8564	24.2425
3	5.9Ø949	5.15318	7.84Ø75	41.Ø887
4	2.7911	5.Ø2157	5.74512	6Ø.9333
5	.592677	2.19117	2.26991	74.864

IMPEDANCE AT OUTPUT LOOKING TOWARD SOURCE, TOWARD LOAD

NO.	REAL	IMAG	REAL	IMAG
Ø	Ø	Ø	95.8781	159.274
1	2Ø.8332	3.98843	51.1355	59.2586
2	77.6969	28.2566	22.7135	69.4398
3	47.7923	35.7941	4Ø.Ø444	128.274
4	79.8866	55.8939	2Ø6.339	757.935
5	6Ø.2526	32.6776	1ØØØØ.	Ø

ACTUAL VOLTAGES AT OUTPUT

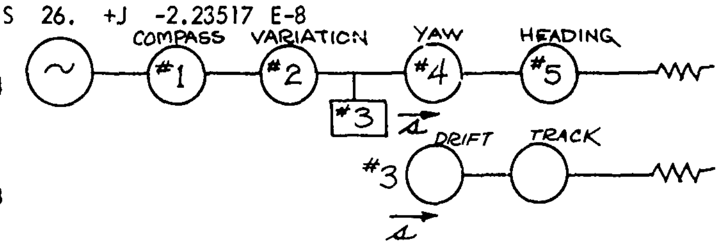
NO.	REAL	IMAG	MAGNITUDE	PHASE
Ø	26.	-2.23517 E-8	26.	-4.92558 E-8
1	9.38362	2.73177	9.77317	16.2313
2	3.49227	4.45624	5.66162	51.9145
3	3.49227	4.45624	5.66162	51.9145
4	2.2Ø4Ø4	4.7442	5.23117	65.Ø811
5	.596195	2.17611	2.2563	74.6779

CURRENT AND POWER AT OUTPUT

NO.	REAL	IMAG	REAL	IMAG
Ø	7.21291 E-2	-.119822	1.87536	-3.11536
1	.1Ø4746	-6.79629 E-2	1.16855	-.351597
2	7.28319 E-2	-2.64689 E-2	.3723	.23212
3	3.93993 E-2	-1.49254 E-2	.2Ø41Ø4	.123449
4	6.5645Ø E-3	-1.12Ø84 E-3	1.97859 E-2	2.86729 E-2
5	5.96195 E-5	2.17611 E-4	-4.38ØØ1 E-4	2.59477 E-4

RECALCULATED SOURCE VOLTAGE IS 26. +J -2.23517 E-8

RAN 12.33 SEC
4 DATA Ø,Ø,Ø,Ø,Ø,4Ø.Ø444,128.274
RUN



FILE SIZE LIMIT

CNET** 16:56 ST FRI Ø9/Ø6/68

CASCADED NETWORKS

NO. TYPE IMPEDANCES

```
 1  1  54      26Ø      16      6Ø       88       22
       T  46.7523  138.Ø31  8.75228  -61.9694  7.24772  121.969
 2  2  37.3333   152     5Ø.6667  162.667  62.6667  17.3333
       T  25.3755  1.39552  38.7Ø89  12.Ø625   11.9578  15Ø.6Ø4
 3  Ø  Ø   Ø  Ø  Ø  4Ø.Ø444  128.274
 4  2  37.3333   152     5Ø.6667  162.667  62.6667  17.3333
       T  25.3755  1.39552  38.7Ø89  12.Ø625   11.9578  15Ø.6Ø4
 5  1  195      76Ø     38.6667  165.333  24Ø  8Ø
       T  167.195  42Ø.973  1Ø.8616  -173.694  27.8Ø51  339.Ø27
```

SOURCE VOLTAGE IS 26 +J Ø
SOURCE IMPEDANCE IS Ø +J Ø
LOAD IMPEDANCE IS 1ØØØØ +J Ø

THEVENIN EQUIVALENT VOLTAGES AT OUTPUT

NO.	REAL	IMAG	MAGNITUDE	PHASE
Ø	26	Ø	26	Ø
1	11.8369	1.73366	11.9632	8.33236
2	9.899	4.45766	1Ø.8564	24.2425
3	5.37Ø79	5.16Ø44	7.44819	43.8554
4	2.52624	4.87731	5.49273	62.6173
5	.5Ø92Ø3	2.11415	2.17461	76.4574

IMPEDANCE AT OUTPUT LOOKING TOWARD SOURCE, TOWARD LOAD

NO.	REAL	IMAG	REAL	IMAG
Ø	Ø	Ø	97.36Ø3	158.Ø86
1	2Ø.8332	3.98843	51.Ø891	56.912
2	77.6969	28.2566	2Ø.Ø222	64.1371
3	43.7Ø53	36.1538	4Ø.Ø444	128.274
4	78.Ø396	54.6678	2Ø6.339	757.935
5	6Ø.Ø864	32.3733	1ØØØØ.	-2.433Ø7 E-6

ACTUAL VOLTAGES AT OUTPUT

NO.	REAL	IMAG	MAGNITUDE	PHASE
Ø	26.	-6.7Ø552 E-8	26.	-1.47767 E-7
1	9.32458	2.7Ø237	9.7Ø827	16.1621
2	3.22557	4.36Ø7	5.424Ø2	53.5Ø96
3	3.22557	4.36Ø7	5.424Ø2	53.5Ø96
4	1.9842	4.6Ø211	5.Ø1163	66.6762
5	.512919	2.Ø9988	2.16161	76.2731

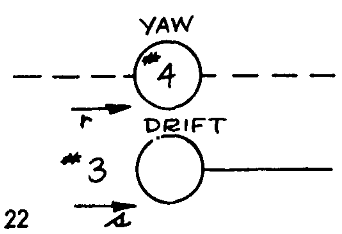
CURRENT AND POWER AT OUTPUT

NO.	REAL	IMAG	REAL	IMAG
Ø	7.34365 E-2	-.11924	1.9Ø935	-3.1ØØ25
1	.1Ø774	-6.71249 E-2	1.186Ø3	-.334758
2	7.62585 E-2	-2.64855 E-2	.361472	.24711
3	3.81292 E-2	-1.32427 E-2	.18Ø736	.123555
4	6.31646 E-3	-8.98317 E-4	1.66673 E-2	2.72866 E-2
5	5.12919 E-5	2.Ø9988 E-4	-4.14639 E-4	2.15413 E-4

RECALCULATED SOURCE VOLTAGE IS 26. +J -6.7Ø552 E-8

```
RAN      12.33 SEC
5 DATA  1,37.3333,152,5Ø.6667,162.667,62.6667,17.3333
6 DATA  1,47Ø,177Ø,1Ø8,44Ø,59Ø,19Ø
RUN
FILE SIZE LIMIT
CNET**       17:Ø2  ST FRI Ø9/Ø6/68
CASCADED NETWORKS
NO. TYPE  IMPEDANCES
 1  1  54     26Ø     16      6Ø      88      22
          T 46.7523  138.Ø31  8.75228 -61.9694  7.24772  121.969
 2  2  37.3333  152  5Ø.6667  162.667  62.6667  17.3333
          T 25.3755  1.39552  38.7Ø89  12.Ø625  11.9578  15Ø.6Ø4
 3  Ø  Ø  Ø  Ø  Ø  4Ø.Ø444  128.274
 4  1  37.3333  152  5Ø.6667  162.667  62.6667  17.3333
          T 28.4758  -.538ØØ5  41.8Ø92  1Ø.129  8.85749  152.538
 5  1  47Ø   177Ø   1Ø8   44Ø   59Ø   19Ø
          T 4ØØ.223  925.59  38.2235  -4Ø4.41  69.7765  844.41

  SOURCE VOLTAGE IS    26   +J   Ø
 SOURCE IMPEDANCE IS   Ø +J  Ø
  LOAD IMPEDANCE IS    1ØØØØ    +J  Ø
```



THEVENIN EQUIVALENT VOLTAGES AT OUTPUT

NO.	REAL	IMAG	MAGNITUDE	PHASE
Ø	26	Ø	26	Ø
1	11.8369	1.73366	11.9632	8.33236
2	9.899	4.45766	1Ø.8564	24.2425
3	5.37Ø79	5.16Ø44	7.44819	43.8554
4	2.44965	4.98585	5.55514	63.8337
5	.597942	2.39653	2.47	75.9899

IMPEDANCE AT OUTPUT LOOKING TOWARD SOURCE, TOWARD LOAD

NO.	REAL	IMAG	REAL	IMAG
Ø	Ø	Ø	96.4121	158.258
1	2Ø.8332	3.98843	5Ø.5497	57.9597
2	77.6969	28.2566	19.9229	67.Ø832
3	43.7Ø53	36.1538	39.4444	14Ø.559
4	83.3289	53.4878	539.42	1755.32
5	156.[illegible]34	66.4333	1ØØØØ	-3.84481 E-6

ACTUAL VOLTAGES AT OUTPUT

NO.	REAL	IMAG	MAGNITUDE	PHASE
Ø	26.	-1.49Ø12 E-8	26.	-3.28372 E-8
1	9.34373	2.72993	9.73437	16.2865
2	3.32122	4.46859	5.56765	53.3785
3	3.32122	4.46859	5.56765	53.3785
4	2.19Ø19	4.86194	5.33248	65.7491
5	.6Ø4122	2.35559	2.43183	75.6152

CURRENT AND POWER AT OUTPUT

NO.	REAL	IMAG	REAL	IMAG
Ø	7.29952 E-2	-.11982	1.89788	-3.11531
1	.1Ø66Ø9	-6.82316 E-2	1.18239	-.3465Ø2
2	7.47252 E-2	-2.73165 E-2	.37Ø245	.243192
3	3.56174 E-2	-1.36335 E-2	.179216	.11388
4	2.88118 E-3	-3.62338 E-4	8.Ø7199 E-3	1.32145 E-2
5	6.Ø4122 E-5	2.35559 E-4	-5.18386 E-4	2.84613 E-4

RECALCULATED SOURCE VOLTAGE IS 26. +J -1.49Ø12 E-8

```
ON AT  11:44   ST Ø9/17/68
    TTY 12

USER NUMBER—T521ØØ
SYSTEM—BAS
NEW OR OLD—OLD
OLD FILE NAME—CNET**
WAIT.

READY

1 DATA 1
5 DATA Ø,77.6969,28.2566,22.7135,69.4398,
5 DATA Ø,77.6969,28.2566,Ø,Ø,22.7135,69.4398
1Ø DATA 9.899,4.45766,Ø,Ø
15 DATA IE6,Ø
RUN


CNET**    11:47   ST Ø9/17/68

CASCADED NETWORKS

NO. TYPE        IMPEDANCES
 1  Ø  77.6969   28.2566   Ø  Ø   22.7135   69.4398

  SOURCE VOLTAGE IS  9.899     +J   4.45766
SOURCE IMPEDANCE IS  Ø +J   Ø
  LOAD IMPEDANCE IS  1ØØØØØØ  +J   Ø

THEVENIN EQUIVALENT VOLTAGES AT OUTPUT
NO.          REAL              IMAG              MAGNITUDE         PHASE
 Ø           9.899             4.45766           1Ø.8564           24.2425
 1           3.49226           4.45623           5.66162           51.9145

IMPEDANCE AT OUTPUT LOOKING TOWARD SOURCE, TOWARD LOAD
NO.          REAL              IMAG              REAL              IMAG
 Ø           Ø                 Ø                 1ØØ.415           97.6932
 1           29.Ø41            31.8679           1.ØØØØØ  E 6      Ø

ACTUAL VOLTAGES AT OUTPUT
NO.          REAL              IMAG              MAGNITUDE         PHASE
 Ø           9.899             4.45766           1Ø.8564           24.2425
 1           3.49231           4.45599           5.66145           51.9126

CURRENT AND POWER AT OUTPUT
NO.          REAL              IMAG              REAL              IMAG
 Ø           7.28324  E-2      -.Ø26466          .838945           6.26751  E-2
 1           3.49231  E-6      4.45599  E-6      -7.65966  E-6     3.11234  E-5

RECALCULATED SOURCE VOLTAGE IS  9.899     +J    4.45766
```

RAN 9.17 SEC
15 DATA Ø,-5Ø
RUN

CNET** 11:51 ST Ø9/17/68

CASCADED NETWORKS

NO. TYPE IMPEDANCES
1 Ø 77.6969 28.2566 Ø Ø 22.7135 69.4398

SOURCE VOLTAGE IS 9.899 +J 4.45766
SOURCE IMPEDANCE IS Ø +J Ø
LOAD IMPEDANCE IS Ø +J -5Ø

THEVENIN EQUIVALENT VOLTAGES AT OUTPUT

NO.	REAL	IMAG	MAGNITUDE	PHASE
Ø	9.899	4.45766	1Ø.8564	24.2425
1	3.49226	4.45623	5.66162	51.9145

IMPEDANCE AT OUTPUT LOOKING TOWARD SOURCE, TOWARD LOAD

NO.	REAL	IMAG	REAL	IMAG
Ø	Ø	Ø	141.227	-76.1169
1	29.Ø41	31.8679	-8.51417 E-9	-5Ø.

ACTUAL VOLTAGES AT OUTPUT

NO.	REAL	IMAG	MAGNITUDE	PHASE
Ø	9.899	4.45766	1Ø.8564	24.2425
1	8.22144	-.879485	8.26835	-6.1Ø593

CURRENT AND POWER AT OUTPUT

NO.	REAL	IMAG	REAL	IMAG
Ø	4.11325 E-2	5.37329 E-2	.167648	.715257
1	1.75897 E-2	.164429	.289226	1.33637

RECALCULATED SOURCE VOLTAGE IS 9.899 +J 4.45766

RAN 9.ØØ SEC
15 DATA Ø,-31.8679
RUN

CNET** 11:54 ST Ø9/17/68

CASCADED NETWORKS

NO. TYPE IMPEDANCES
1 Ø 77.6969 28.2566 Ø Ø 22.7135 69.4398

SOURCE VOLTAGE IS 9.899 +J 4.45766
SOURCE IMPEDANCE IS Ø +J Ø
LOAD IMPEDANCE IS Ø +J -31.8679

THEVENIN EQUIVALENT VOLTAGES AT OUTPUT

NO.	REAL	IMAG	MAGNITUDE	PHASE
Ø	9.899	4.45766	1Ø.8564	24.2425
1	3.49226	4.45623	5.66162	51.9145

IMPEDANCE AT OUTPUT LOOKING TOWARD SOURCE, TOWARD LOAD

NO.	REAL	IMAG	REAL	IMAG
Ø	Ø	Ø	89.6639	-23.4Ø67
1	29.Ø41	31.8679	-2.45Ø42 E-8	-31.8679

ACTUAL VOLTAGES AT OUTPUT

NO.	REAL	IMAG	MAGNITUDE	PHASE
Ø	9.899	4.45766	1Ø.8564	24.2425
1	4.89ØØ2	-3.83221	6.21274	-38.Ø848

CURRENT AND POWER AT OUTPUT

NO.	REAL	IMAG	REAL	IMAG
Ø	9.12Ø76 E-2	7.35249 E-2	.575115	1.1344
1	.12Ø253	.153447	1.176Ø8	.289521

RECALCULATED SOURCE VOLTAGE IS 9.899 +J 4.45766

RAN 9.33 SEC
15 DATA Ø,-53
RUN

CNET** 11:58 ST Ø9/17/68

CASCADED NETWORKS

NO. TYPE IMPEDANCES
1 Ø 77.6969 28.2566 Ø Ø 22.7135 69.4398

SOURCE VOLTAGE IS 9.899 +J 4.45766
SOURCE IMPEDANCE IS Ø +J Ø
LOAD IMPEDANCE IS Ø +J -53

```
THEVENIN EQUIVALENT VOLTAGES AT OUTPUT
NO.          REAL          IMAG          MAGNITUDE     PHASE
 Ø           9.899         4.45766       1Ø.8564       24.2425
 1           3.49226       4.45623       5.66162       51.9145
IMPEDANCE AT OUTPUT LOOKING TOWARD SOURCE, TOWARD LOAD
NO.          REAL          IMAG          REAL          IMAG
 Ø           Ø             Ø             158.853       -83.4831
 1           29.Ø41        31.8679       -4.68489 E-9  -53.
ACTUAL VOLTAGES AT OUTPUT
NO.          REAL          IMAG          MAGNITUDE     PHASE
 Ø           9.899         4.45766       1Ø.8564       24.2425
 1           8.34939       -.297844      8.3547        -2.Ø43
CURRENT AND POWER AT OUTPUT
NO.          REAL          IMAG          REAL
RAN     8.83  SEC

15 DATA Ø,-56
RUN
WAIT.


CNET**     12:Ø2   ST  Ø9/17/68
CASCADED NETWORKS

NO. TYPE        IMPEDANCES
 1  Ø   77.6969   28.2566    Ø    Ø   22.7135   69.4398

  SOURCE VOLTAGE IS  9.899   +J  4.45766
SOURCE IMPEDANCE IS  Ø  +J  Ø
  LOAD IMPEDANCE IS  Ø  +J  -56
THEVENIN EQUIVALENT VOLTAGES AT OUTPUT
NO.          REAL          IMAG          MAGNITUDE     PHASE
 Ø           9.899         4.45766       1Ø.8564       24.2425
 1           3.49226       4.45623       5.66162       51.9145
IMPEDANCE AT OUTPUT LOOKING TOWARD SOURCE, TOWARD LOAD
NO.          REAL          IMAG          REAL          IMAG
 Ø           Ø             Ø             179.96        -88.2535
 1           29.Ø41        31.8679       -5.178Ø7 E-9  -56.
ACTUAL VOLTAGES AT OUTPUT
NO.          REAL          IMAG          MAGNITUDE     PHASE
 Ø           9.899         4.45766       1Ø.8564       24.2425
 1           8.39327       .24Ø366       8.39671       1.64Ø37
CURRENT AND POWER AT OUTPUT
NO.          REAL          IMAG          REAL          IMAG
 Ø           3.45499 E-2   4.17138 E-2   .156Ø64       .566936
 1           -4.29224 E-3  .14988        -7.2Ø519 E-2  1.25695
RECALCULATED SOURCE VOLTAGE IS   9.899   +J  4.45766
```

```
RAN        8.83  SEC
NEW
NEW FILE NAME—UUU
READY.

1Ø  LET C=  1/(2*3.14159*8ØØ*55)
2Ø PRINT C
RUN


UUU        12:Ø7      ST  Ø9/17/68

3.61716  E-6  Farad

RAN             1.ØØ  SEC
BYE

***OFF AT 12:Ø7   ELAPSED TERMINAL TIME=    23 MIN.
```

The propeller was exposed to varying degrees of turbulence and high speed motion pictures were taken during the periods of exposure. The pictures showed the blades bending and twisting in the t· rbulent air. Reversal of rotation of the propeller occassionally occurred. Blade failures were induced that duplicated the appearance of those noted in the field. In severe turbulence, all four blades would have failed within seconds. In smooth air, the blades lasted indefinitely. Introducing an angle of attack of 7 degrees did not noticeably affect results. This investigation appeared to rule out collisions with rain drops and insects as a causative factor.

Replacement propellers were ordered to an amended specification which specified a life of 1000 hours for the propellers at 190 knots. The vendor supplied propellers with a flatter pitch. To date, no in-flight failures of the redesigned propellers have occurred, alth ugh a blade of one propeller did fail in unknown circumstances on the ground.

The appearance of this failure was similar to many of the in-flight failures; i.e., the blade separated by pulling cleanly out of its slot in the hub. The epoxy fillet at the root parted along the bond line at the hub. A characteristic of many of the blade failures has been this evidence of poor adhesion of the epoxy, which indicates improper surface preparation.

2.2.13 Log Amplifier Change

The output of the AMPD-224 Phase IV detector was a linear function of input CN level. The detector output consisted of three ranges; 0 to 5000 cn/cc, 0 to 20,000 CN/cc and 0 to 50,000 cn/cc. The usefulness of the detector output signal was improved by installing a modification that made the Detector output approximately a logarithmic function of input CN level covering the entire 0 to 50,000 CN/cc on one range. This change prevented the loss of signal information due to saturation in the presence of strong signals, while maintaining sensitivity to weak signals, when low background levels existed.

The logarithmic output of the detector was obtained by using a diode/resistor parallel combination on the feedback loop of an operational amplifier. The diode created a logarithmic gain characteristic for the amplifier. Different values of this resistor were tried, until the desired amplifier gain characteristics were obtained. The gain characteristics of the log-amp shifted (at a constant slope) with temperature variations. This temperature sensitivity caused the log-amp output to change inversely with temperature. The temperature problem was eliminated by using the base-emitter diode junction on a μa726 integrated circuit device which maintained constant internal temperature through internal sensing and power dissipation.

Calibration data was measured 25 Oct 68 on three production logarithmic amplifiers installed in three AMPD-224 detectors. The data was smoothed and converted to the table (table 2-1) of digital count versus nuclei/cc. This table was to be used in the digital computer programing effort to convert detector output to nuclei/cc. The detector logarithmic output curve is shown in figure 2-7.

The logarithmic detector output characteristics made a change necessary in the alarm detection circuit of the analyzer. To maintain the same alarm ratios, the alarms had to be determined from a voltage difference rather than a specified ratio between the detector output and background voltages. The alarm detection change (see Analyzer Modification No. 3—para 2.2.17) was implemented in the level detector modules of the analyzer.

TABLE 2-1. CALIBRATION DATA FOR AMPD-224 LOGARITHMIC DETECTOR OUTPUT

Digital Count	Nuclei/CC	Digital Count	Nuclei/CC
0	200	32	5200
1	200	33	5590
2	200	34	6000
3	200	35	6450
4	200	36	6930
5	330	37	7450
6	450	38	8000
7	550	39	8600
8	660	40	9240
9	760	41	9930
10	860	42	10660
11	970	43	11460
12	1080	44	12320
13	1210	45	13240
14	1340	46	14220
15	1470	47	15280
16	1600	48	16420
17	1750	49	17640
18	1900	50	18950
Transition to Straight Line to 50,000			
19	2040	51	20360
20	2200	52	21890
21	2360	53	23520
22	2540	54	25270
23	2720	55	27150
24	2930	56	29170
25	3140	57	31340
26	3380	58	33670
27	3630	59	36170
28	3900	60	38900
29	4190	61	41790
30	4510	62	44900
31	4840	63	48240

The log-amp modifications were checked out in the 224-AMPDSystem on 28 October, 1968 (figure 2-8); the results follow.

2.2.13.1 Detectors: (Log-Amp Output) Two 10-cycle and one 5-cycle detectors were installed in the system.

1. All three detectors produced approximately the same voltage output. No tracking problems were found.

2. No increase in the normal noise content of the detector output was found.

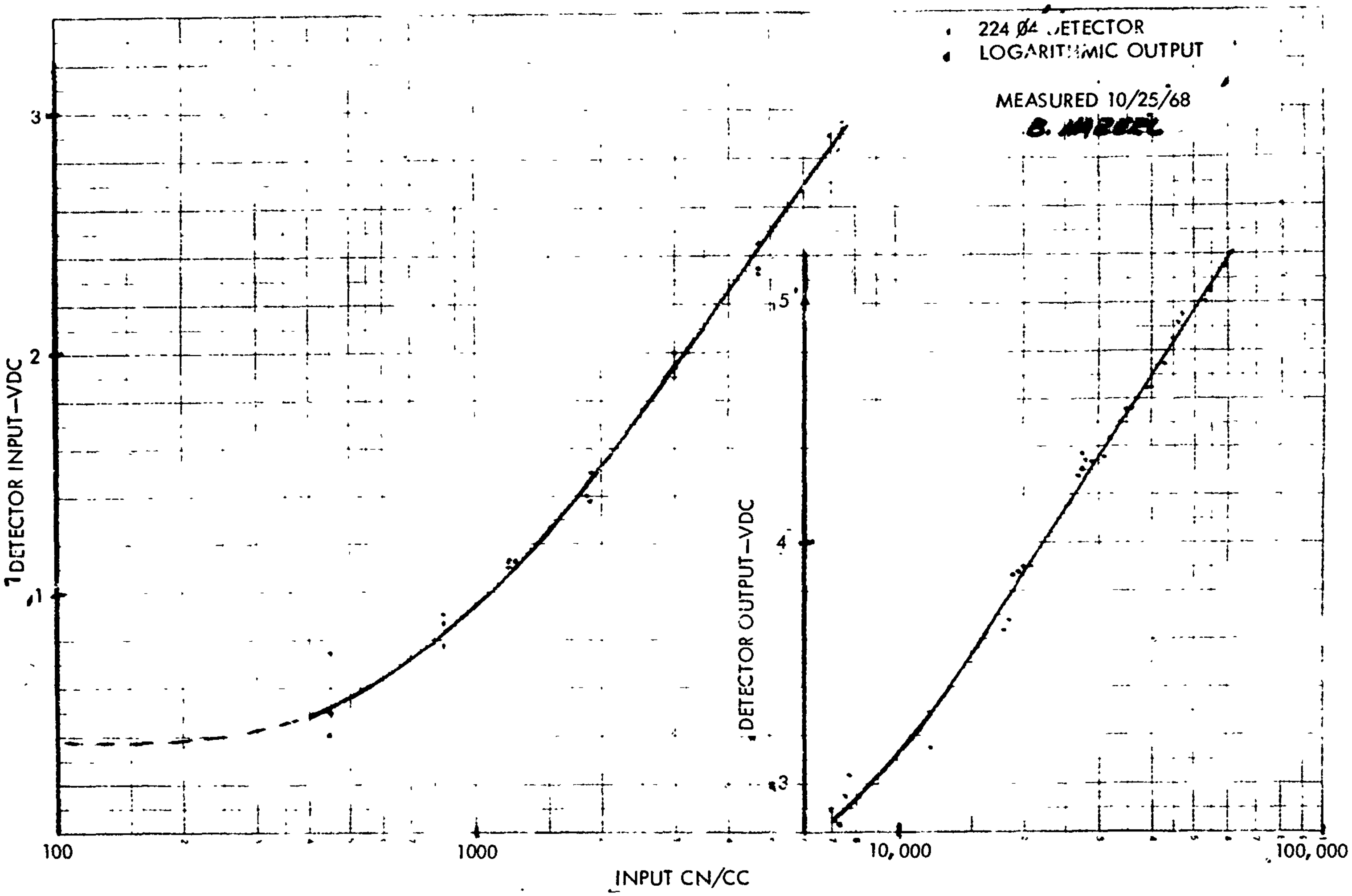


Figure 2-7. AMPD-224 Phase IV Detector Logarithmic Output.

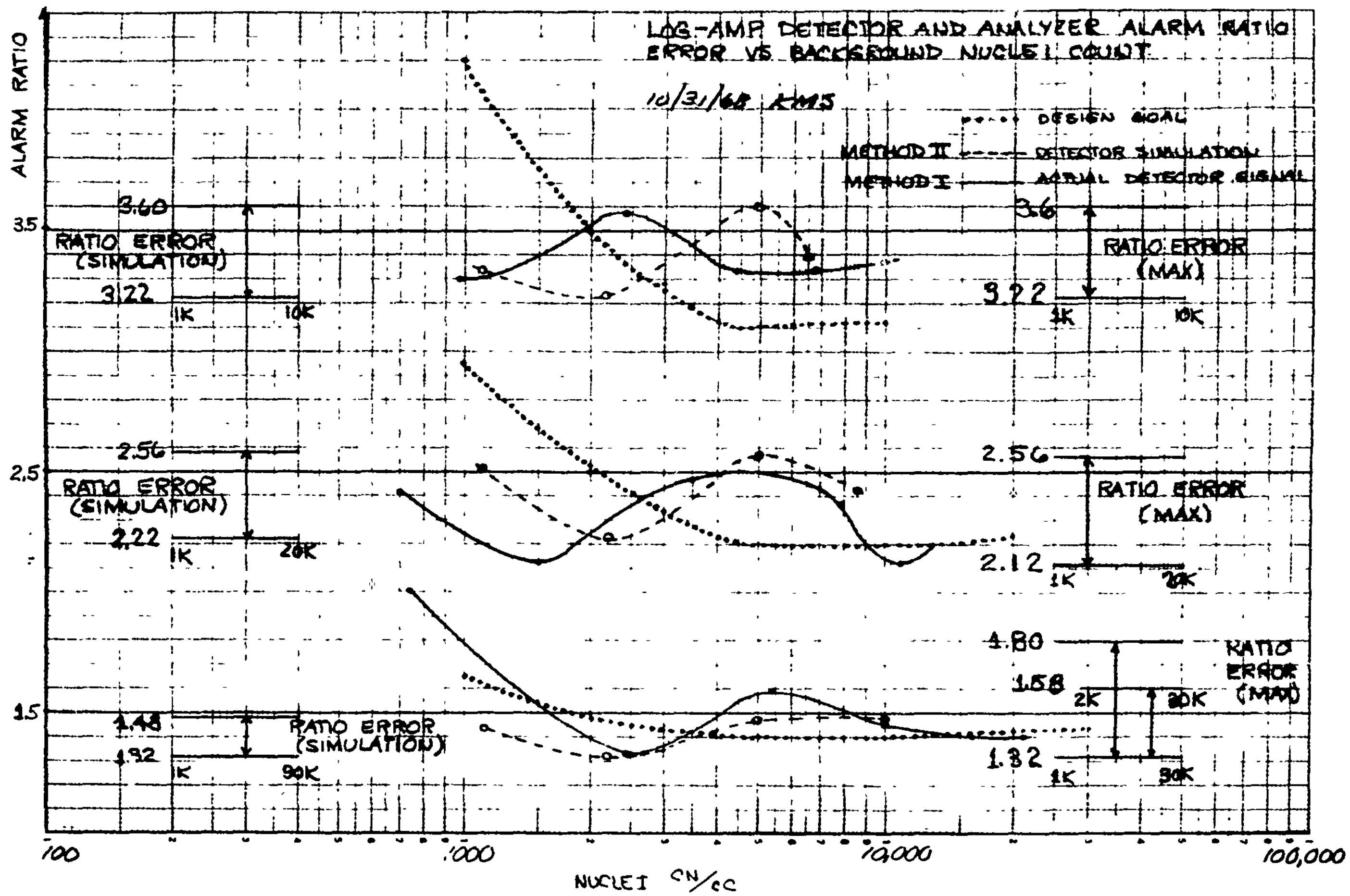


Figure 2-8. Log-Amp Detector and Analyzer Alarm Ratio Error vs Background Nuclei Count.

2.2.13.2 Analyzer (Alarm Modified)

1. All modifications were checked, and operated properly.

2. The background was found to be in error. After background integration, a 15-percent error remained between the background voltage and the simulated detector voltage.

   This error may be due to an improper offset voltage setting in the analyzer integrator. The problem will be investigated at GEOS.

2.2.13.3 Detector/Digital Data Subsystem Interface

1. The digital readout of detector output was found to track the detector voltage output. An accuracy check was not possible, since the detector output could not be held constant enough.

2.2.13.4 Analyzer/Digital Data Subsystem Interface

1. Analyzer discrete data readouts were found to be normal.

2. The digital readout of analyzer background was within specifications of 1 BIT.

2.2.13.5 Analyzer/Detector Interface

1. The analyzer indication of detector output, accurately tracked the detector output on all channels.

2. Analyzer range modification interfaced properly with the detectors.

3. The alarm ratio error between the analyzer and detector was found to be acceptable.

2.2.13.5.1 Ratio Error. The ratio error (figure 2-8) was evaluated in the following manner:

1. Method 1 (Actual Detector Signal)

   The CN count to the detector (Ch 3) was adjusted until a constant detector output was achieved. The detector output voltage was measured at the detector and recorded.

   The analyzer background voltage was then adjusted until each alarm (1.5, 2.5 and 3.5) point was reached. The background voltage at each alarm point was measured using the digitaldata subsystem and recorded.

   The measured voltages were converted to CN/cc using the output characteristics of the (log-amp) detector. From this data, the alarm ratios were calculated and plotted on the attached graph.

NOTE: The measurement of the detector output using this method is at best a good approximation. However, it does provide a measure of ratio error without simulation of the actual system.

2. Method 2

The detector voltage was developed by simulation, using the test potentiometer on the system test panel; the simulated detector signal was measured using the digital data subsystem. A scope was used to measure the detector output voltage.

The background voltage at the alarm points and the alarm ratios were determined in the same manner as in Method 1.

This method provides a measure of ratio error to the accuracy of the digital data subsystem.

3. Results (figure 2-8)

The plot of ratio error vs background, indicates that the results of both methods produce similar curves.

The indicated ratio error (max) is a gross error, taking the maximum error of both Method 1 and Method 2. A more realistic ratio error is found by looking at Method 1 (detector simulation), where accurate measurements were possible. The ratio error is found to be acceptable.

The results of Method 2 show that a simulation produces results similar to the results with actual system signals.

2.2.14 Optical Tape Reader

In December, 1967, a Digitronics high speed punched tape reader was loaned for investigation. Significant reductions in tape readin time could be effected by incorporating this reader into the Mk 12 ground support setup.

In January, 1968, a new Digitronics punched tape reader was installed to speed up tape readin operation, and effort begun on a special bootstrap routine to operate with the new reader.

By May, 1968, the Digitronics tape reader was successfully operated at 300-frame/sec speed with the Mk 12 computer using a new, short bootstrap subroutine. One Digitronics reader was ordered for field use, with delivery originally scheduled 16 weeks ARO. Delivery was later delayed to December, 1968.

2.2.15 Program Changes

Wind calibration program effort was initiated in September, 1967, with the object of providing precise wind solutions in flight. By December, 1967, it was decided that the precise wind solution would be completed only if time permitted prior to the flight tests scheduled for March 1968. By March, 1968, the need for precise wind solution program was eliminated.

In April, 1968, reduction of Florida test data had resulted in a new math model which was currently being programed. In addition, the Mk 12 was to be programed to perform some analysis of detector signals. Both of these program efforts were due for completion for use in Florida tests in June, and were significant changes in the scope of Phase IV program reguirements.

In June, 1968, the major effort was the writing, debugging, and system test of three major program revisions:

1. New math model
2. Addition of pulse analysis routines
3. Incorporation of further revised and improved pulse analysis routines.

In August, 1968, the software was changed to allow:

1. Averaging input values, including true track.
2. Incorporating operator-selected variable source size into the math model.
3. Incorporating double-plot capability into the math model, including ability to back-track to plume center for second plot.

Debugging was required on these three program changes. On August 26, it was decided to put a moratorium on further math model changes. However, a significant pulse analysis program change was initiated on this date for the October Louisiana tests.

A Fortran simulation of the present math model and new pulse analysis program was requested, and contact made with Fort Huachuca personnel concerning Fortran processing of selected data records at GEOS.

2.2.16 Playback Tape Reader

Early in 1967, a requirement for on-ground magnetic tape playback was generated. However, by June 1967, a decision was made to drop magnetic tape readers from the Phase IV system, since they are not required by contract and represent a change not presently anticipated.

2.2.17 Analyzer Modifications

The AMPD-224 Phase IV analyzer has undergone eight modifications, as follows:

1. Prevention of background zero-volt condition modification.
2. Time constant modification to the A1-B1003 integrator modification.
3. Detector logarithmic output—alarm criteria modification.
4. V Detector/V background final steady state correspondence modification.
5. 50K range lock modification.
6. Background and offset stabilization modification.
7. Integrating operational amplifier offset voltage stabilization.
8. Transmitter initiate signal modification.

The modifications are described in detail as follows.

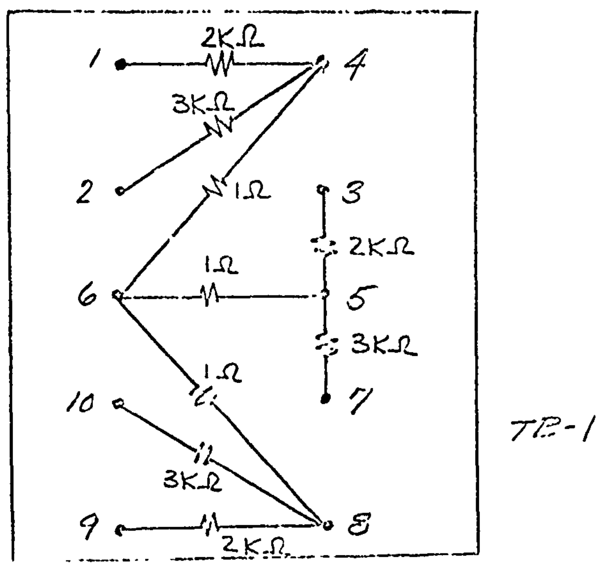
2.2.17.1 Modification 1/Prevent Background Zero Volt Condition. It was planned to add three resistors to the level detector module, to ensure that V background can never drop below 0.1 volt on the 5K range. The change could not be implemented in this manner, because the level detector module could not accommodate the added components. Therefore, the required resistors were placed on a terminal strip and located on the analyzer backplate. Wiring changes (figure 2-9) required were:

1. The level detector modules was modified as follows:

   a. The connection between the 240-ohm resistor and -15 vdc was removed.

   b. The altered end of the 249-ohm resistor was brought out to P2-8 on the level detector.

2. Terminal board-five sets of terminals were added to the analyzer backplate. The terminal designations are shown in Sketch 1.



Sketch 1

3. The following wire changes were implemented in the analyzer cabling.

   a. The connection between the S1-C range switch pole position and the background potentiometer (CW) terminal on all three channels was removed.

   b. The connection between the background potentiometer (CCW) terminal and the microammeter pin 3 for all three channels was removed.

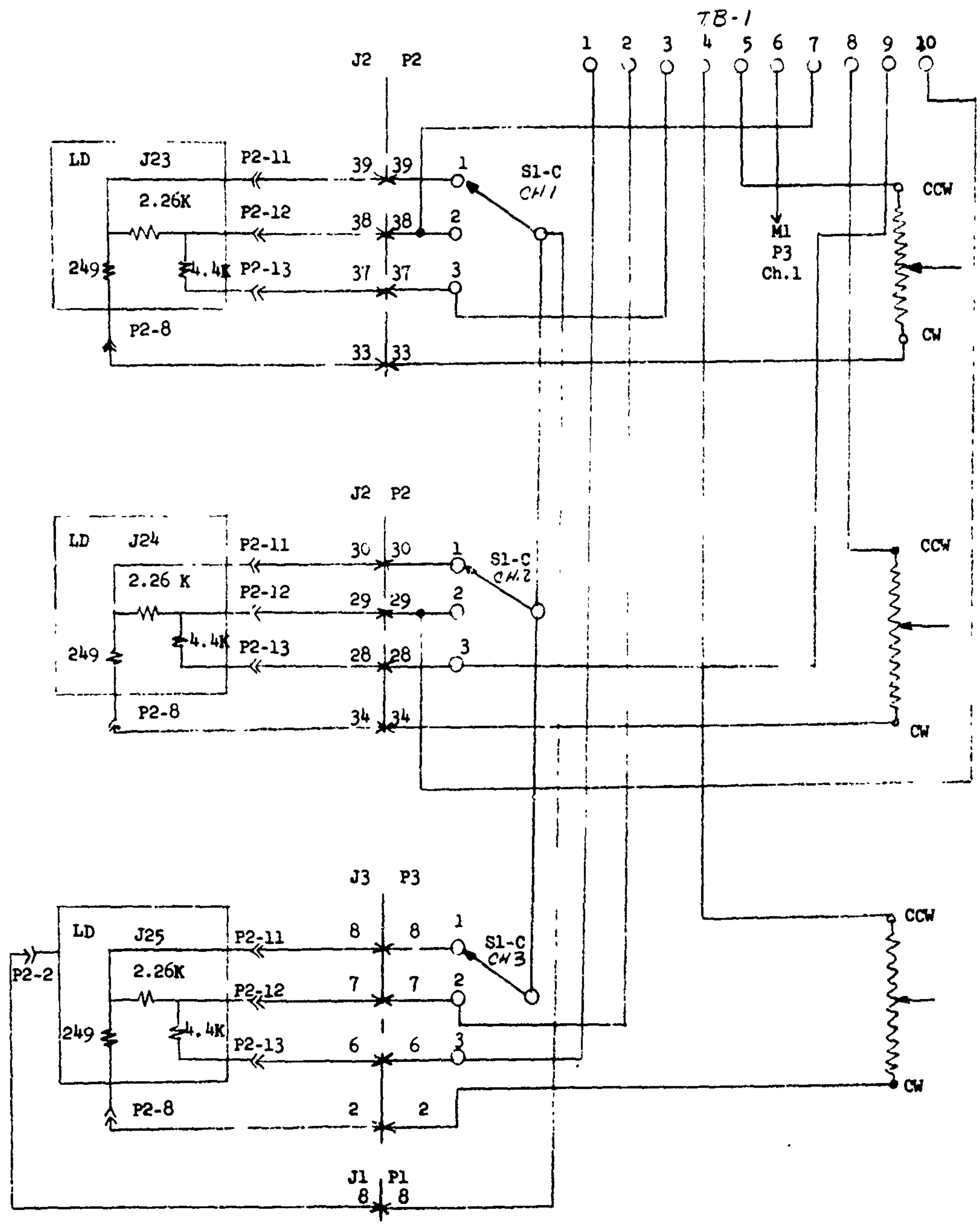


Figure 2-9. Modification No. 1.

c. The following wires were added:

TB6-5 to CH 1 Bgn'd Pot Terminal CCW
TB6-8 to CH 2 Bgn'd Pot Terminal CCW
TB6-4 to CH 3 Bgn'd Pot Terminal CCW
P2-23 to CH 1 Bgn'd Pot Terminal CW
P2-34 to CH 2 Bgn'd Pot Terminal CW
P3-2 to CH 3 Bgn'd Pot Terminal CW
TB6-7 to S1-C Pos 2 CH 1
TB6-3 to S1-C Pos 3 CH 1
TB6-10 to S1-C Pos 2 CH 2
TB6-9 to S1-C Pos 3 CH 2
TB6-2 to S1-C Pos 2 CH 3
TB6-1 to S1-C Pos 3 CH 3
S1-C CH 3-Pole Pos to S1C Ch 2-Pole Pos
S1-C CH 2-Pole Pos to S1C-Ch 1-Pole Pos
S1-C CH 1-Pole Pos to P1-8
TB6-6 to M1 Pin 3 Ch 1

4. The Wire-Wrap plate was modified as follows (additions):

Add J23-P2-8 to J2-33
Add J24-P2-8 to J2-34
Add J25-P2-8 to J3-2
Add J25-P2-2 to J1-8

2.2.17.2 Modification No. 2/A1-B1003 Integrator Time Constant. The following changes were made to decrease the integration time for the background voltage potentiometer.

1. 5K Range:

Changed the 1-μf capacitor to a 0.33-μf capacitor

2. 20K Range:

Changed the 0.22-μf capacitor to a 0.082-μf capacitor

3. 50K Range:

Changed the 0.10-μf capacitor to a .033-μf capacitor

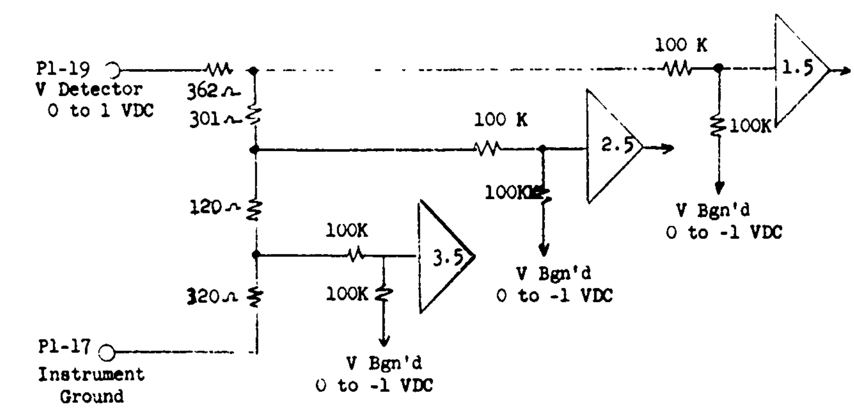
These changes were made in the feedback motor drive module, by Circuits Engineering.

2.2.17.3 Modification No. 3/Detector Logarithmic Output—Alarm Criteria. The level detector modules were modified as shown in figure 2-10, which shows the detecting circuit before and after modification. See figure 2-10.

2.2.17.4 Modification No. 4/V Detector/V Background Final Steady State Correspondance. Figure 2-11 shows the feedback motor drive module before and after change.

NOTES: 1. Level Detector Module. The range change operational amplifiers were removed by cutting runs.
2. Background Meter. A 50-ohm resistor was added in series with the (-) terminal of the background microammeter.

Level detecting circuit before change:



Level Detecting Circuit after change:

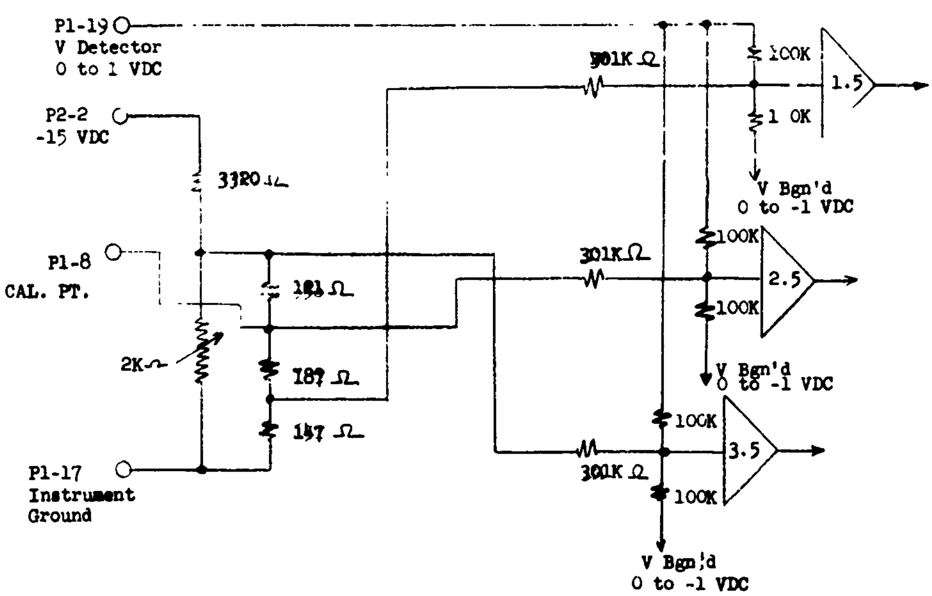


Figure 2-10. Level Detecting Circuit Before and After Change.

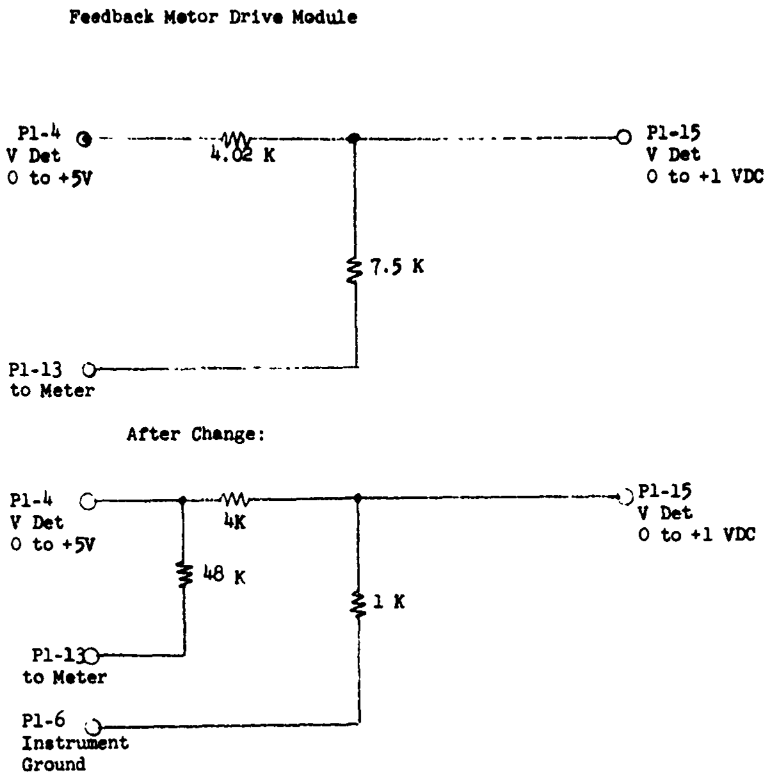


Figure 2-11. Modification No. 4/V Detector Before and After Change.

2.2.17.5 Modification No. 5/50K Range Lock. The 50K range was set on all channels, and the following wires were removed from the Wire-Wrap plate:

CH 2: were from J27-01 to J2-07

CH 3: were from J28-01 to J2-16

The wire from CH 1 5K pushbutton pin 3 was removed; wire was insulated with heat-shrink tubing.

2.2.17.6 Modification No. 6/V Background—V Offset Stabilization. The level detector modules were modified as shown in figure 2-12 (before and after change).

1. Analyzer Wiring. The following wires were removed from the resistor terminal board (TB-1) and insulate with heat-shrunk tubing.

TB1-1 to CH 3 S1-C-3
TB1-2 to CH 3 S1-C-2
TB1-3 to CH 1 S1-C-3
TB1-7 to CH 1 S1-C-2
TB1-9 to CH 2 S1-C-3
TB1-10 to CH 2 S1-C-2

2.2.17.7 Modification No. 7/Integrating Operational Amplifier Offset Voltage Stabilization. The feedback motor drive module circuit modifications (before and after change) are shown in figure 2-13.

2.2.17.8 CH 3 Disable Switch/Transmitter Initiate Signal. The CH 3 Disable Switch was modified to supply a ground signal to the analyzer output connector pin (J5-Z) during CH 3 Enable. The modification was accomplished as follows:

1. A wire was added from CH 2 Disable Switch (pin 1) to the malco connector P1-36.

2. A wire was added from the output connector (J5-z) to the malco connector P1-37.

3. The following wires were added to the Wire-Wrap plate:

J1-36 to J16-20
J16-19 to J16-29
J16-29 to J20 P2-10
J16-39 to J1-37

2.3 FINAL CONFIGURATION

The AMPD-224 System final configuration is basically that defined in para 2.1, changed and modified as outlined in para 2.2. The system performs the same mission as the Phase II system, but does not have real time analog recording capability. From a system display point of view, the Phase IV system has an accurate source location readout; the plotter gives an indication for a target off-map and, therefore, not plotted; and the plotter pen lifts when going out to mark a target. The present position repeater is eliminated, and TMG is always displayed on the VSI.

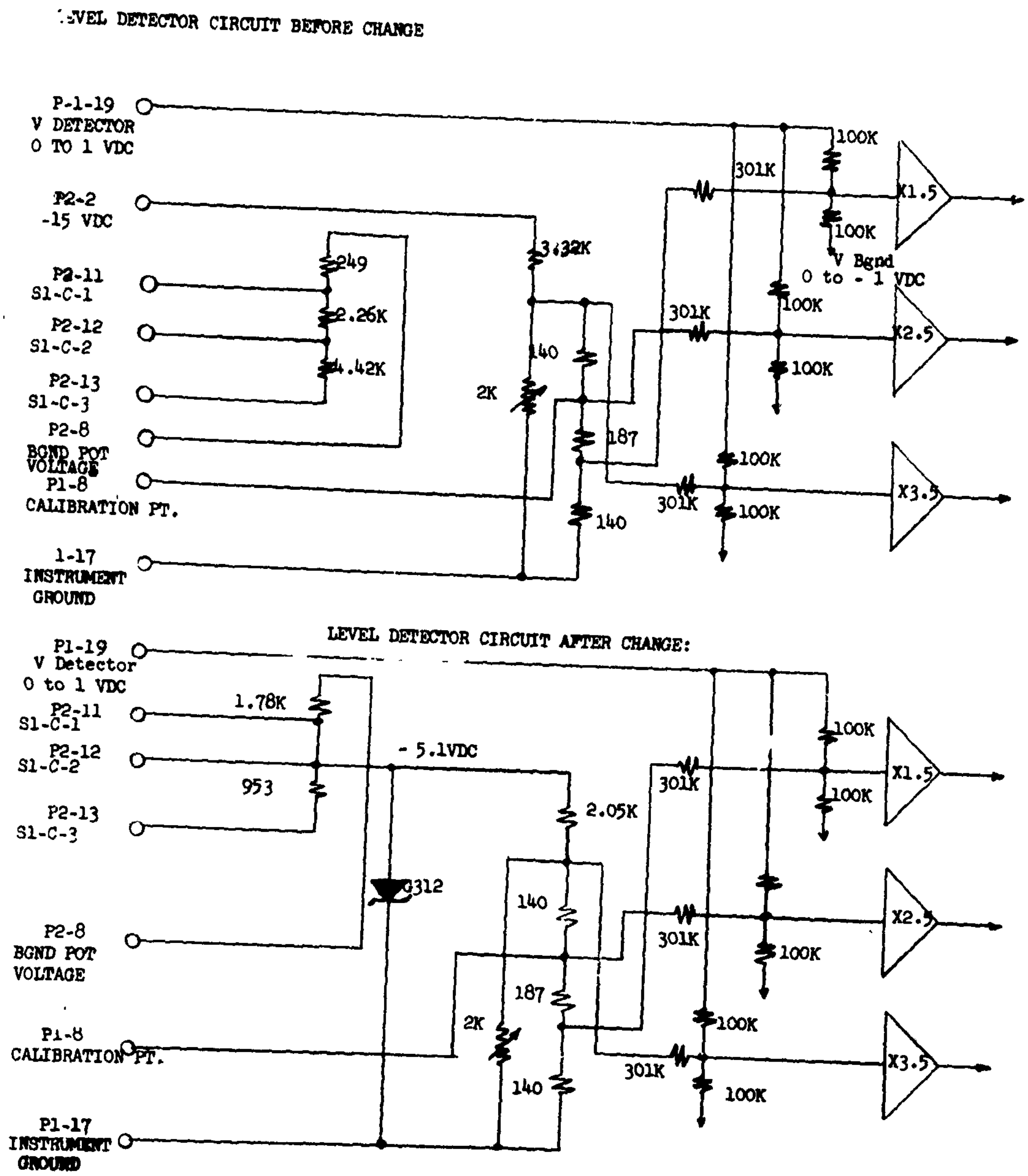


Figure 2-12. Level Detector Circuit Before and After Change.

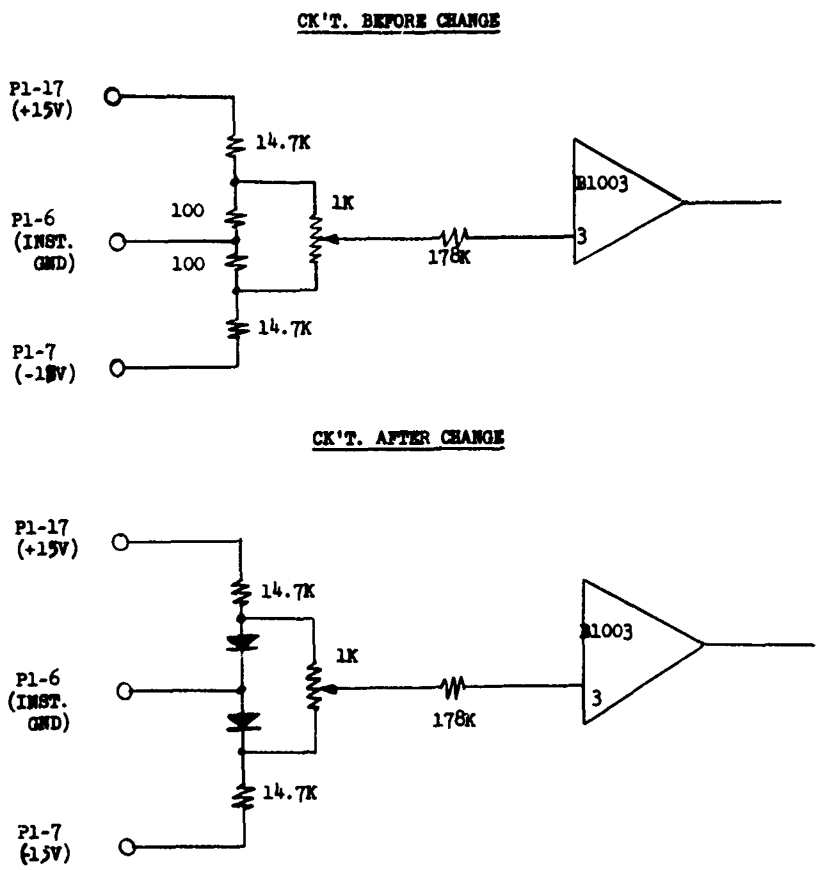


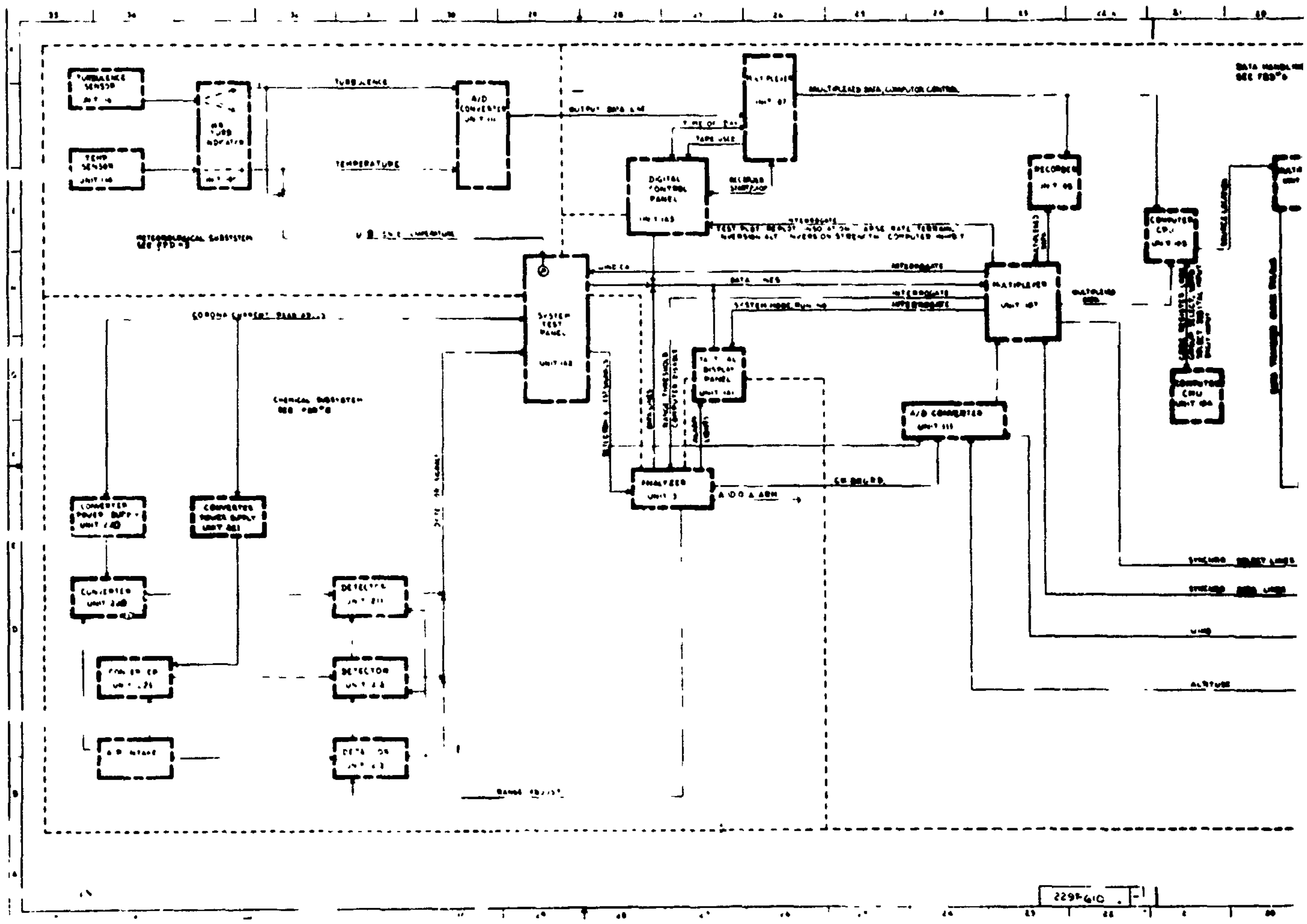
Figure 2-13. Feedback Motor Drive Module Circuit Before and After Change.

2

Wiring has been included to allow easy incorporation of self-destruct, and the three detector-analyzer scales are replaced with a single logarithmic output. The computer program is an updated version and includes an S—quess and a double plot. A more rugged turbulance propeller is used, and the side-slip sensor synchro lines are balanced with a capacitor network. An optical reader allows a much more rapid computer program readin.

Many refinements made to the Phase IV system were later incorporated into Phase II system. These include the ground isolation fix (to allow a single ground among the data handling subsystem, the plotter and the navigator); the detector and converter modification; the system noise fix (with the analog filter box and the S/D input filter), and the precise wind solution, eliminating the need for the wind calibrate mode prior to a mission flight.

The final configuration is shown functionally in figure 2-14. A complete description is contained in the documentation package which is listed in para 3.13.



TEMPERATURE
A/D CONVERTER
SYSTEM TEST PANEL
DIGITAL CONTROL PANEL
MULTIPLEXER
RECORDER
A/D CONVERTER
DETECTOR
DETECTOR
ANALYZER

1

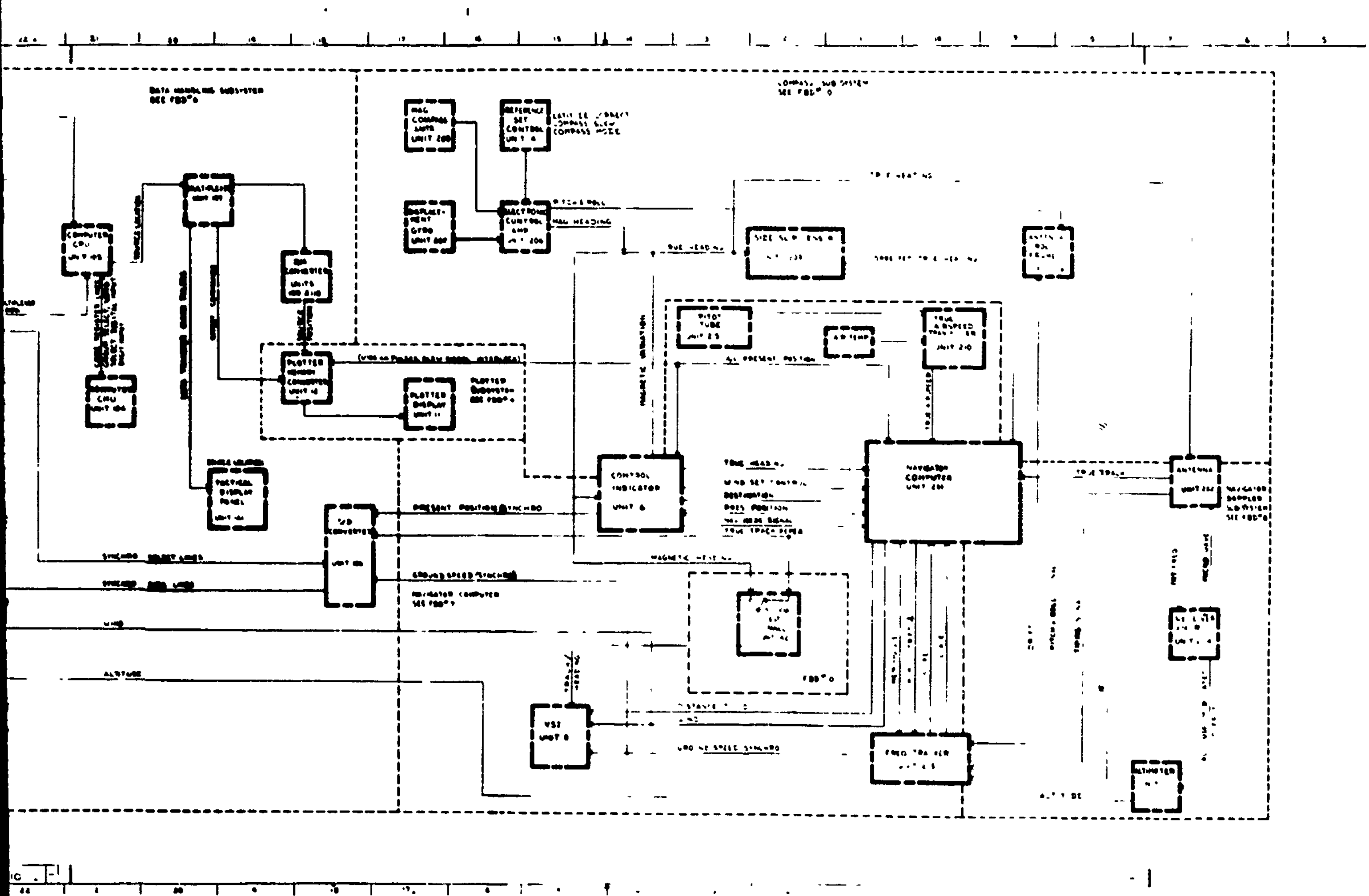


Figure 2-14. AMPD-224 System/Functional Block Diagram.

2

Section 3

PHASE IV PROGRAM EVENTS

3.1 SCOPE/PHASE IV

The system design, fabrication, installation, and checkout events are discussed in section 3. Para 3.1 presents an overview of the Phase IV program with the PERT charts that were generated for the latter program events. Also discussed are the specific design activities; the fabrication phase with photographs; the system test of System 1; the installation and checkout on the UH1-D and the two OV-1's, and the field testing performed on both systems. Major design changes and modifications performed throughout the Phase IV program were discussed in section 2, but are referenced in the appropriate design activity paragraph within this chapter.

The early portion of the Phase IV activity was devoted primarily to adapting the Phase II configuration to the OV-1 interface. Several modifications (discussed in para 2.1) were incorporated at that time. As program activities were formalized, a Performance Evaluation Review Technique (PERT) network was developed to reflect the activities which followed system fabrication. The finalized charts are presented in figures 3-1 and 3-2.

3.2 SYSTEM DESIGN

3.2.1 Pods

System design activity started with the basic Phase II design, making the modifications noted in para 2.1. The same general layout was maintained and documented. Several system design studies were made during the early stages of the program, some of which are discussed in the equipment sections of this report, and others which will be discussed in this section.

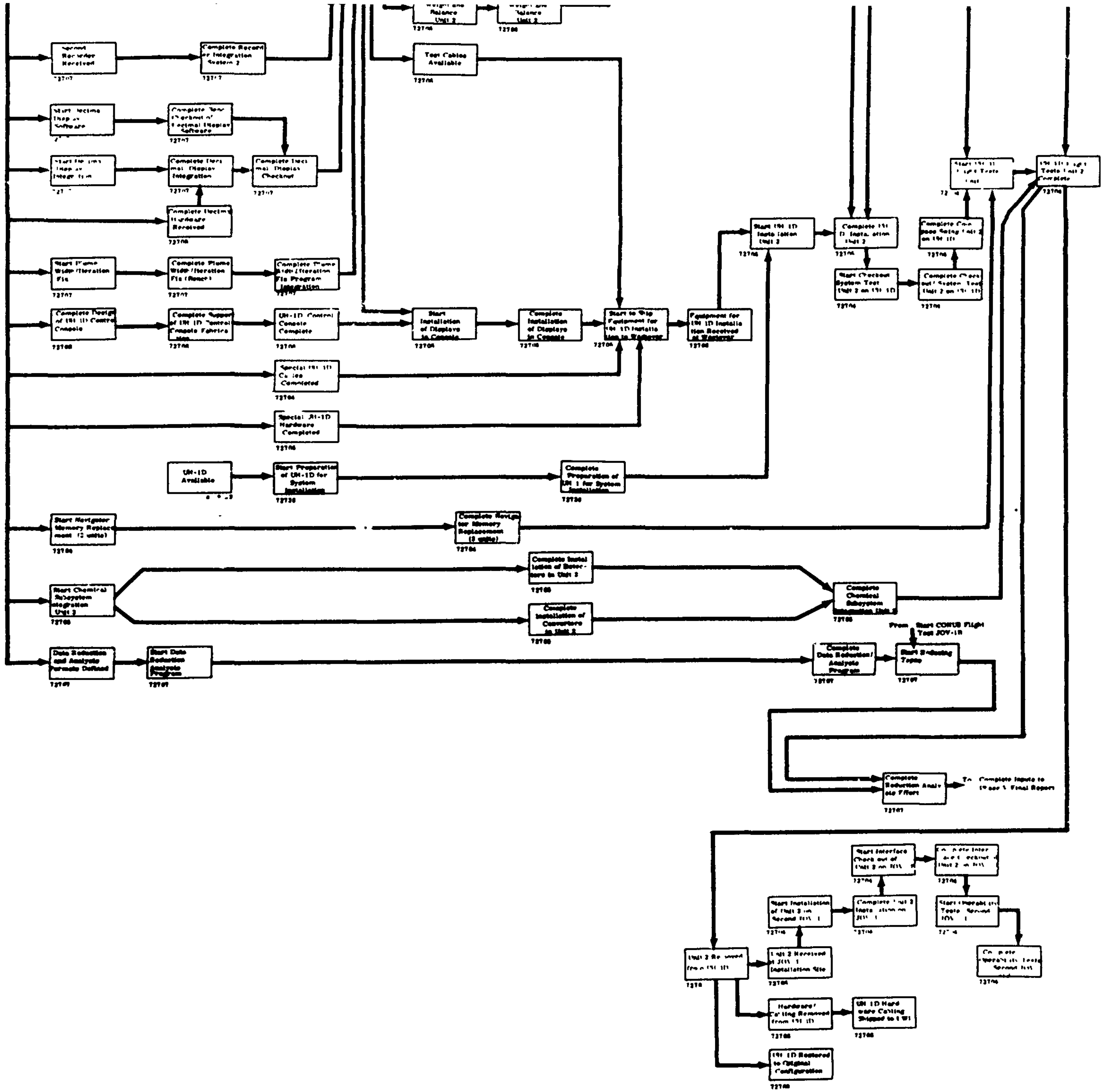
Early efforts concerned preparation for pod design and attention was given to equipment weights and volumes, heating and cooling, and location of pod c.g's. The documentation package contains the equipment layouts in the pods and in the aircraft. The pod design considerations are discussed in para 3.3.1; pod weights are listed in tables 3-1 and 3-2; aircraft units are listed in table 3-3, and tables 3-4 and 3-5 summarize Pod 1 and Pod 2 units, respectively.

3.2.2 Control and Display

The control and display function was considered from both the human factors and the system design point of view. This design represents a major departure from the Phase II configuration. In the C-47 Phase II system, panel space is not a limitation, and the AMPD operator is located remotely from the pilot as opposed to the limited panel space and the AMPD operator being in the cockpit. Because of these differences, a major effort was put into the control and display requirements to minimize panel size and to give an optimum panel design. The operator panel functions are listed in table 3-6.

TABLE 3-1. WEIGHT ESTIMATE/POD 1 PHASE IV

Item No.	Component	Dwg or Catalog No.	No./System	Weight/lbs
2	Temp sensor		1	2.0
4	Comp pwr supply	1656457	1	10.0
5	Comp mem unit	1689020	1	34.3
6	Comp proc unit	1689021	1	52.5
7	Shock Mt (CPS)	Cat. No. 5205-HT	4	0.9
8	Mounting base (CMU)	Type 15330	1	2.2
9	Mounting base (CPU)	Type 15330	1	2.2
10	Cooling fans for 4, 5, 6	Part No. 19A907	6	1.0
11	Tape recorder	D-1616-1430	1	50.0
12	Syn/Dig Converter	SK-660907	1	26.0
13	A/D converter	107-1127	1	1.0
14	D/A converter	107-1126	2	2.0
15	Power supply	107-1125	1	1.0
16	Mounting base	AOAL-BIB-A10	1	2.2
17	Terminal Boards		2	4.0
18	MUX Box and pack (MUX)		1	40.0
20	Computer pwr sw		1	Neg
21	Phone jack		1	Neg
22	MUX pwr supply	Abbot T6D 6.3A	1	5.2
23	MUX pwr supply	Abbot TID-6.3A	1	1.8
24	MUX pwr supply	Abbot T2D-15.7A	1	2.0
25	MUX pwr supply	Model 501 Burr-Brown	1	1.0
26	Pod	5434628-509		100.0
27	Cabling			15.0
28	Pod skin reinforcement			40.0
29	Spine and brackets			60.0
30	Paint			10.0
31	Ballast			--
32	Self-Destruct feature			2.0
		TOTAL WEIGHT POD NO. 1		465.75 lbs


Test Cables Available
Start Installation of Displays in Console
Complete Installation of Displays in Console
Special UH-1D Hardware Completed
UH-1D Available
Start Preparation of UH-1D for System Installation
Start Navigator Memory Replacement (2 units)
Start Chemical Subsystem Integration Unit 2
Complete Chemical Subsystem Integration Unit 2
Data Reduction and Analysis Formats Defined
Start Data Reduction Analysis Program
Complete Data Reduction/ Analysis Program
Start Reducing Tapes
From Start CONUS Flight Test JOV-1B
To Complete Inputs to Phase I Final Report
Hardware/ Cabling Removed from UH-1D
UH-1D Hardware Cabling Shipped to CWI
UH-1D Restored to Original Configuration

1

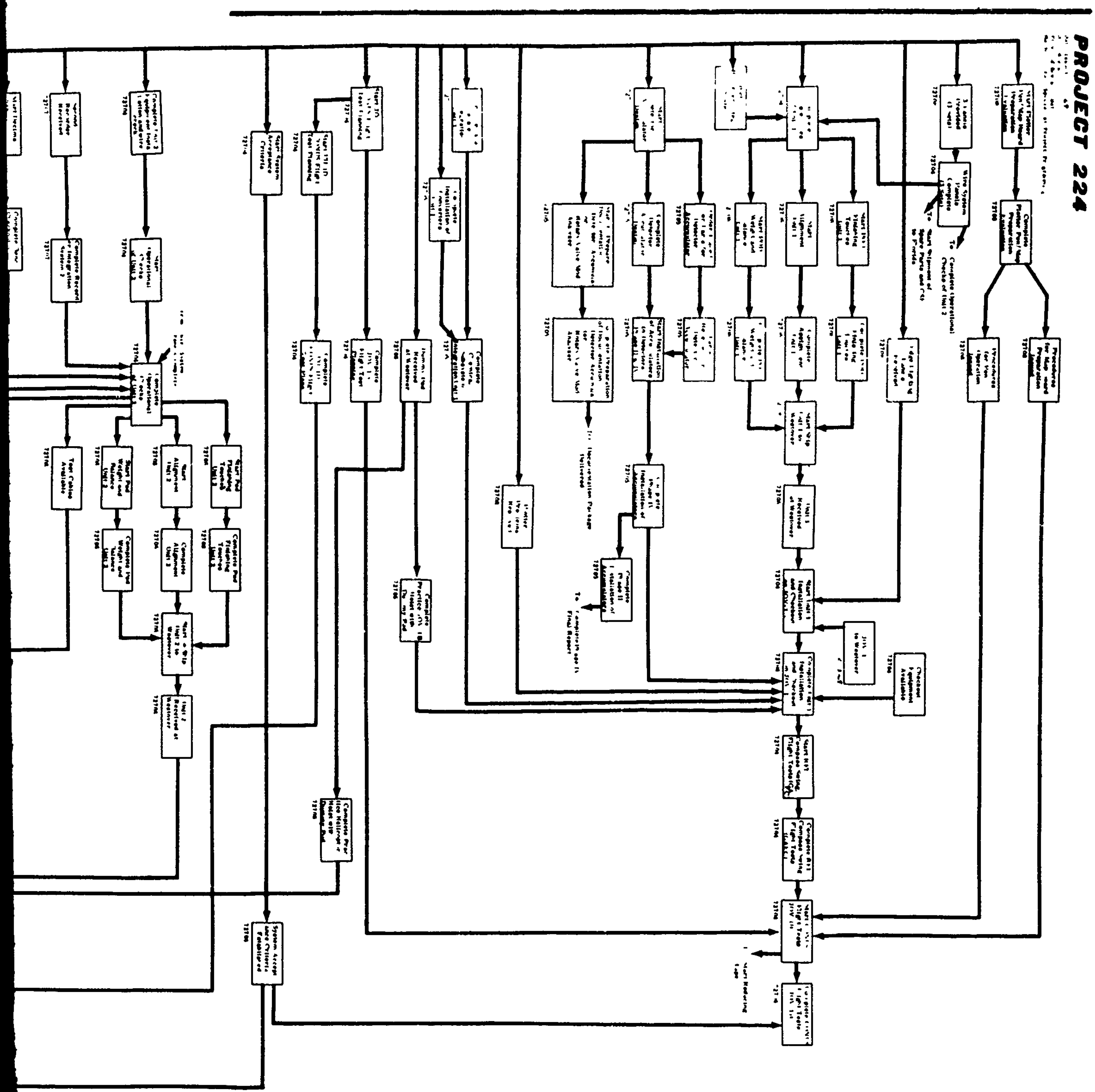
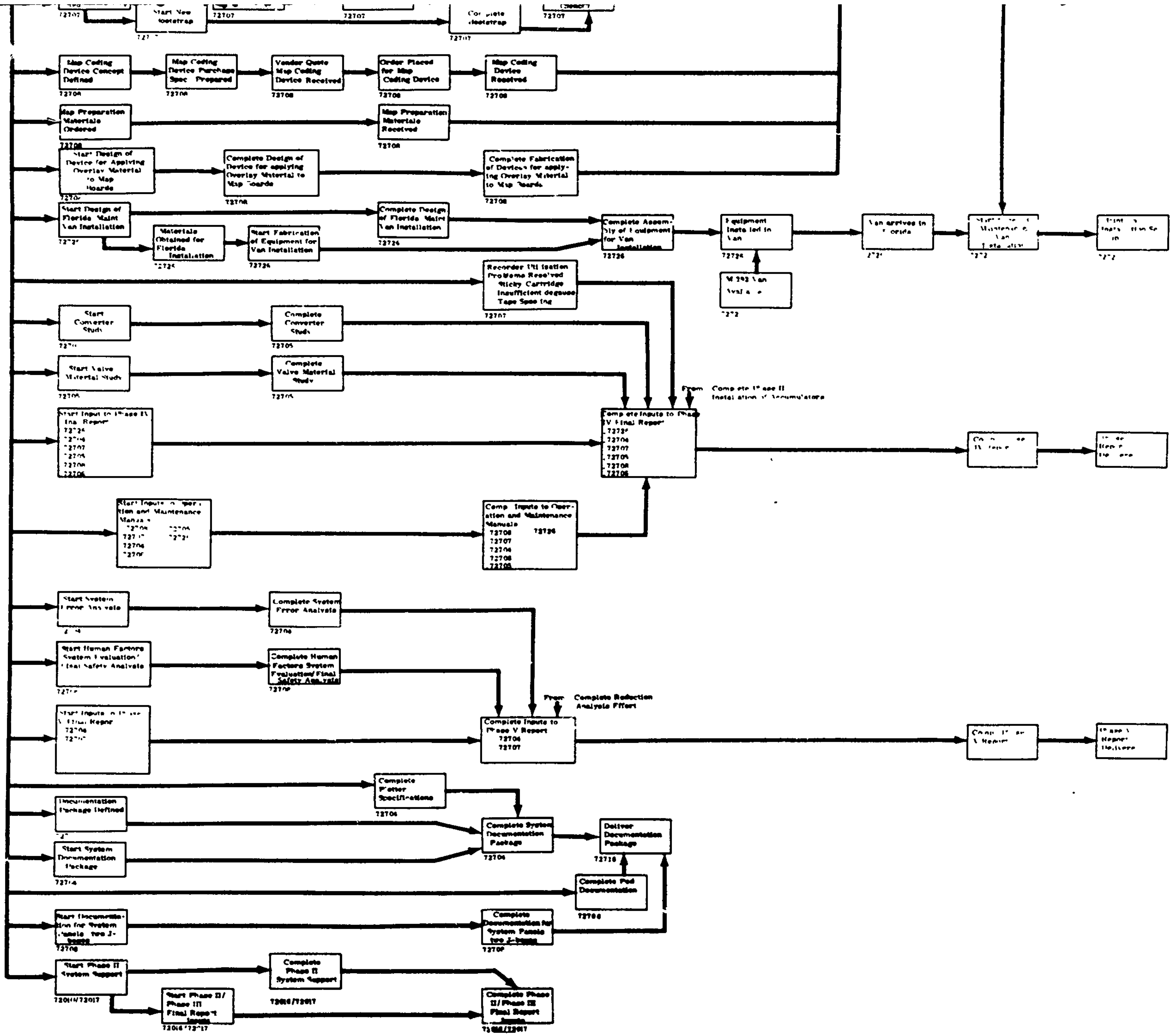


Figure 3-1. PERT Network Part 1/Project 224.

2



Map Coding Device Concept Defined
72708
Map Coding Device Purchase Spec Prepared
Vendor Quote Map Coding Device Received
72708
Order Placed for Map Coding Device
72708
Map Coding Device Received
72708
Map Preparation Materials Ordered
72708
Map Preparation Materials Received
72708
Start Design of Device for Applying Overlay Material to Map Boards
Complete Design of Device for applying Overlay Material to Map Boards
72708
Complete Fabrication of Devices for applying Overlay Material to Map Boards
72708
Start Design of Florida Maint Van Installation
Materials Obtained for Florida Installation
Start Fabrication of Equipment for Van Installation
72726
Complete Design of Florida Maint Van Installation
72726
Complete Assembly of Equipment for Van Installation
72726
Equipment Installed in Van
72726
Van arrives in Florida
Recorder Utilization Problems Received Sticky Cartridge Insufficient degauss Tape Spooling
72707
Start Converter Study
Complete Converter Study
72705
Start Valve Material Study
72705
Complete Valve Material Study
72705
From Complete Phase II Installation of Accumulators
Complete Inputs to Phase IV Final Report
72704
72707
72705
72708
72706
Comp Inputs to Operation and Maintenance Manuals
72706
72707
72704
72708
72705
72726
Start System Error Analysis
Complete System Error Analysis
72704
Start Human Factors System Evaluation/Final Safety Analysis
Complete Human Factors System Evaluation/Final Safety Analysis
From Complete Reduction Analysis Effort
Complete Inputs to Phase V Report
72704
72707
Complete Plotter Specifications
72704
Documentation Package Defined
Complete System Documentation Package
72704
Deliver Documentation Package
72718
Start System Documentation Package
Complete Pod Documentation
72708
Start Documentation for System Panels two J-boxes
72708
Complete Documentation for System Panels two J-boxes
Start Phase II System Support
72016/72017
Complete Phase II System Support
72016/72017
Start Phase II/Phase III Final Report Inputs
Complete Phase II/Phase III Final Report Inputs
72016/72017

1

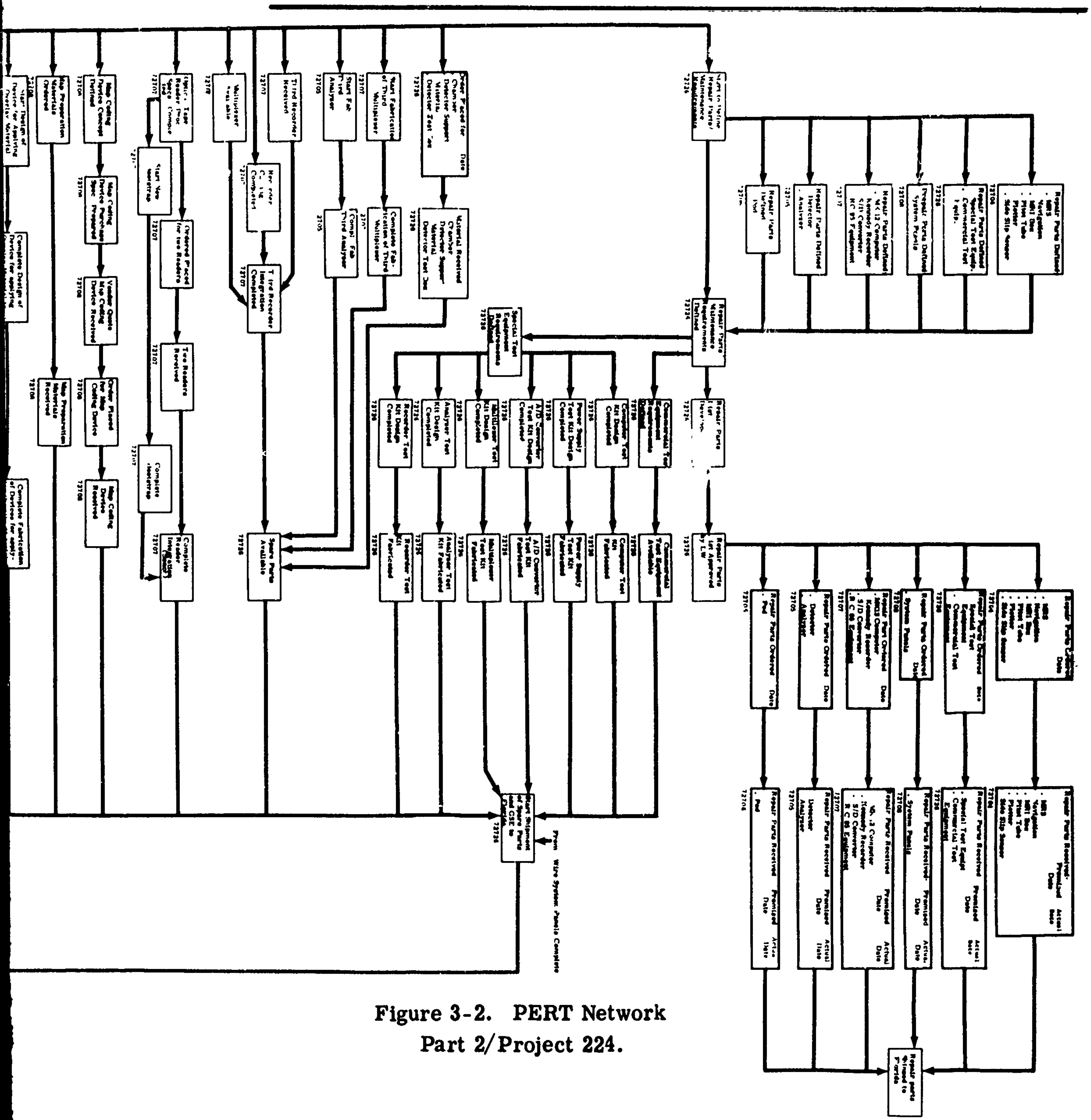


Figure 3-2. PERT Network
Part 2/Project 224.

2

TABLE 3-2. WEIGHT ESTIMATE/POD 2 PHASE IV

Item No.	Component	Dwg or Catalog No.	No./System	Weight/lbs
1	TAS Xmtr temp sensor	ES-F-187096	1	3.75
2	Slip sensor		1	2.0
3	Freq tracker	ES-F-187091	1	27.3
4	Computer	ES-F-187094	1	20.3
5	Antenna and gimbal	ES-D-187095	1	26.0
6	Revr-Xmtr	ES-F-187090	1	14.9
7	Heading coupler	3242K40	1	6.3
8	Base for 9	3241K61	1	1.0
9	Platform	3242K38	1	10.5
10	Compass trans.	5472015	1	2.0
11	Junction box	450-985	2	4.0
12	Radome		1	5.0
13	Borescope mount		1	1.0
14	Detector		3	45.0
15	Conv No. 1		1	1.0
16	Conv No. 2		1	1.0
17	DC-DC Conv		1	1.0
18	Phone jack		1	Neg
19	Pitot tube		1	5.0
20	Antenna cavity		1	5.0
21	Pod	5434628-509	1	100.0
22	Cabling			25.0
23	Pod skin reinforcement			40.0
24	Spine and brackets			36.0
25	Paint			10.0
26	Ballast			--
27	Self-Destruct mechanism			2.0
28	Seals			10.0
		TOTAL WEIGHT POD NO. 2		395.05 lbs

TABLE 3-3. AIRCRAFT UNITS

Unit No.	Unit
1A1	Tactical display panel
1A2	System test panel
1A3	Digital control panel
1A4	Cockpit junction box
2	
3	Analyzer
4	Compass controller
5	
6	Control indicator
7	Altitude indicator
8	Velocity steering indicator
9	Power panel
11	Plotter display
12	Plotter memory converter
13	System junction box
14	Self-Destruct panel
15	Display power supply
50	Pod 2 pylon
51	Pod 1 pylon

TABLE 3-4. POD 1 UNITS

Unit No.	Unit
100	Metro Electronics (MRI)
101	Connector, MRI temperature sensor
102	DRO power supply
103	Computer program unit
104	Computer memory unit
105	Kennedy recorder
106	Synchro-to-digital converter
107	Multiplexer
108	RC-95 power supply
109	RC-95 D/A converter (B)
110	RC-95 D/A converter (A)
111	RC-95 A/D converter
112	Fan 1
113	Fan 2
114	Air temperature sensor (MRI)

Table 3-4. Pod 1 Units (Continued)

Unit No.	Unit
115	
116	Turbulence Sensor (MRI)
117	Filter Box
118	Power Supply ±15V - Burr Brown
119	Power Supply 15V
120	Power Supply +6V
121	Power Supply -6V
122	Connector, maintenance panel power
123	Fan 3
124	Fan 4
125	Fan 5
126	
127	Thermostat
128	Capacitor board

TABLE 3-5. POD 2 UNITS

Unit No.	Unit
200	Computer junction box
201	Navigator computer
202	Antenna
203	Doppler junction box
204	Receiver/Transmitter
205	Frequency tracker
206	Amplifier, electronic control
207	Displacement gyroscope
208	Compass transmitter
209	Side-Slip sensor
210	True air speed transmitter
211	Detector No. 1
212	Detector No. 2
213	Detector No. 3
215	Pitot static tube
216	Roll frame
217	Thermostat, forward
218	Connector, bulkhead mounted
219	Thermostat, rear
220	Corona converter assembly
221	Corona converter assembly
223	Doppler simulator connector
224	Temperature probe
225	Connector, compass transmitter
226	Detector fans
227	Detector fans
228	Detector fans

TABLE 3-6. CONTROL AND DISPLAY FUNCTIONS/OPERATOR PANEL

Equipment and Function	Control			Display				
	Switches	Knob	Other	Meters	Lights	Decimal Readout	Switch Position	Other
UNIT 3—ANALYZER								
Effluent Levels (3)				X				
Background Reference Levels (3)				X				
Detector Scale Factor Display and Manual Selection (3)	X				X		X	
Manual or Auto Detector Scale Factor Selection (3)	X						X	
Fast Background Calculation (3)	X							
Analyzer Alarm Threshold Selection (3)	X						X	
Manual Background Set (3)			Potentiometer	Background Reference				
Manual or Auto Background Selection (3)	X						X	
Audible Alarm Volume ON-OFF	X		Potentiometer					Potentio-meter Position
Analyzer Disable (3)	X				X			
NAVIGATION								
UNIT 8—VELOCITY AND STEERING INDICATOR								
Ground Speed						X		
Track Angle				X				

Table 3-6. Control and Display Functions/Operator Panel (Continued)

Equipment and Function	Control			Display				
	Switches	Knob	Other	Meters	Lights	Decimal Readout	Switch Position	Other
NAVIGATION								
UNIT 8—VELOCITY AND STEERING INDICATOR (Cont)								
Wind or Destination Components								
North				X				
East				X				
Memory Operation								Mechanical Flag
Warning-Doppler Failure or Memory Operation					X			
Desired Track		X						Rotatable Graticule
Scale Selection (short, medium, long)								Mechanical Flag
Wind Set or Read	X						X	
Scale Expand 10X or 3X	X						X	
UNIT 7—ALTITUDE INDICATOR								
Absolute Altitude				X				
UNIT 6—CONTROL INDICATOR								
Present Position Components								
North						X		
East						X		
Destination No. 1 Position Components								
North						X		
East						X		

Table 3-6. Control and Display Functions/Operator Panel (Continued)

Equipment and Function	Control			Display				
	Switches	Knob	Other	Meters	Lights	Decimal Readout	Switch Position	Other
NAVIGATION UNIT 6—CONTROL INDICATOR (Cont)								
Destination No. 2 Position Components								
North						X		
East						X		
Present Position Slew	X						X	
Destination No. 1 Slew	X						X	
Destination No. 2 Slew	X						X	
Destination Selection	X							Shaded Flag
Press to Store	X							
Wind Set Component Slew								
North	X						X	
East	X						X	
Magnetic Variation Set		X				X		
G/S (groundspeed) Slew	X						X	
Drift Slew	X						X	
Mode Selection (OFF, STBY, LAND, SEA, TEST, AIR)	X						X	
Fault Warning and Malfunction Indication					X			

Table 3-6. Control and Display Functions/Operator Panel (Continued)

Equipment and Function	Control			Display				
	Switches	Knob	Other	Meters	Lights	Decimal Readout	Switch Position	Other
NAVIGATION UNIT 4—COMPASS CONTROLLER								
Mode Selection (comp, slaved, d.g.) Directional Gyro	X						X	
Latitude Correction Control		X				X		
Hemisphere Selection	X						X	
Heading Set	X							Compass Ind
Compass Malfunction					X			
Compass Synchronization Indication				X				
UNIT 1A1—TACTICAL DISPLAY								
Analyzer Alarms (9)					X			
Mode: OFF, Test, Operate, Lapse Rate	X					X		
Source Location (2)						X		
Temperature Alarm: Pod 1, Pod 2	X							
Run No.	X							
Pen Lift	X							

Table 3-6. Control and Display Functions/Operator Panel (Continued)

Equipment and Function	Control			Display				
	Switches	Knob	Other	Meters	Lights	Decimal Readout	Switch Position	Other
UNIT 1A2—SYSTEM TEST PANEL								
Temp Turb, Corona Current 1, Corona Current 2	X			X			X	
Corona Current 1			Potentiometer		X			
Corona Current 2			Potentiometer		X			
System Test (light)					X			
System Test (knob)			Potentiometer					
Test—Normal (3)	X							
VSI					X			
Heading—Normal	X							
Lamp Test	X							
UNIT 1A3—DIGITAL CONTROL PANEL								
Lapse Rate	X							
Terrain	X							
Inversion Altitude	X							
Inversion Strength	X							
Man, Insul	X							
Time of Day	X					X		

Table 3-6. Control and Display Functions/Operator Panel (Continued)

Equipment and Function	Control			Display				
	Switches	Knob	Other	Meters	Lights	Decimal Readout	Switch Position	Other
UNIT 1A3—DIGITAL CONTROL PANEL (Cont)								
Reset	X							
Entry	X							
Multiplexer								
Manual					X			
Fault					X			
Recorder								
Running Time						X		
Ready	X				X			
Error					X			
ON-OFF	X							
Computer								
Inter					X			
Prog					X			
Range					X			
Sync					X			
Data					X			
WCM					X			
Invers					X			
Mk XII					X			
Calc: Inhibit Enable	X				X			
Replot	X							
Test Plot	X							
UNIT 11—PLOTTER DISPLAY								
Mode: Off, Stby, On	X						X	
Map Index (2)						X		
Chg Map Indicator					X			

Table 3-6. Control and Display Functions/Operator Panel (Continued)

Equipment and Function	Control			Display				
	Switches	Knob	Other	Meters	Lights	Decimal Readout	Switch Position	Other
UNIT 11—PLOTTER DISPLAY (Cont)								
Dimmer Control (2)		X						Color/ Intensity
Slew	X							Map Position and Min Counters
Map Release			Latch					
Test	X							Motion of Pen
Mark	X							1/4 inch Square
Cover Release			Latch					
A/C Position								Pen Mark
A/C Track								Pen Mark
Source Position								Pen Mark
Event Mark								Pen Mark
UNIT 9—POWER PANEL								
Inverter	X						X	
Compass	X						X	
Nav.	X						X	

Table 3-6. Control and Display Functions/Operator Panel (Continued)

Equipment and Function	Control			Display				
	Switches	Knob	Other	Meters	Lights	Decimal Readout	Switch Position	Other
UNIT 9—POWER PANEL (Cont)								
Pitot Heater	X						X	
Recorder	X						X	
Plotter	X						X	
Pod 1	X						X	
Analyzer	X						X	
Det	X						X	
Converter	X						X	
Computer Memory	X						X	

3.2.3 Vibration Effects

An investigation into the vibration effects on both the pod structure and the wiring due to stress of flexure and abrasion was conducted in April, 1967. GEOS consulted with Aerospace Electronics Department (AED) in Utica, N. Y., and several design parameters were incorporated to ensure minimum vibrational effects. AED also suggested guidelines concerning moisture and condensation in the pods and aircraft. These were incorporated into the design.

3.2.4 Electronic Equipment

RFI represents a continuing problem in the design of electronic equipment. The state of knowledge has improved over the last several years. All the basic circuit analysis techniques apply. However, in their application the real problem is understanding and accounting for the distributed parameters. Most projects cannot afford a complete analysis. Therefore, the approach was to generate a basic set of ground rules for the system based on a limited analysis. This was followed in system and field tests by RFI measurements and appropriate corrective actions.

Ground rules were formulated based on system characteristics utilizing knowledge and information. The Digital Circuits unit established a set of ground rules for DTL circuitry in the POSEIDON fire control system which were utilized.

Inverters are a major source of noise. A study was conducted to determine what MIL specs the inverters meet, and what RF supression is required to meet system requirements. It is possible to generate noise on both the input d-c lines and the output a-c lines.

The aircraft d-c power supply was investigated to determine the degree of ripple being generated by the generator and being fed in by the inverters. A determination was made as to the amount of filtering that should be added.

Grounding one end of a shield is not necessarily the proper approach. In particular, if the line length is longer than $\lambda/50$, where λ is the shortest wave length to which the circuit will respond, then standing waves on the shield can couple into the circuit. The shield in this case was grounded at both ends.

In the case of diode logic, the diode may act as an RF detector causing a voltage to build up and the diode to be biased off. The 16 interrogate lines and the six digital data lines were run in the same cable to reduce the effects of magnetic coupling.

The 5-volt analog excitation line and its return line to the Navigator are a twisted shielded pair, and shield was grounded at the multiplexer end. The synchro signals are twisted shielded wires, and the shield grounded at the receiving end.

3.2.5 Environment

Equipment in Project 224 -Phase IV will be required to operate in an environment of extreme temperature and humidity. In this environment, unprotected circuit boards can be expected to experience corrosion and fungus growth. To protect against these adverse effects, a protective conformal coating can be applied to the circuit boards. Many types of conformal coatings are presently available; properties of three basic types of organic conformal coatings now in use are outlined as follows.

The three organic coatings presently used to coat circuit boards against the effects of humidity and temperature are:

1. Epoxy base
2. Silicone base
3. Polyurethane base

For this application, a conformal coating must have the following properties:

1. Low moisture absorption
2. High temperature range
3. High insulation resistance
4. Fungus prohibitive
5. Easy to apply and remove (reparability)

A comparison of these properties in the three basic types of organic conformal coatings follows:

3.2.5.1 Moisture Absorption: "All present state-of-the-art coatings absorb and are permeable to moisture and gas to some extent. However, organic coatings differ in their permeability rates because of their different molecular structures."

A list of relative permeability characteristics of coatings which can serve as a preliminary selection guide follows in table 3-7.

TABLE 3-7.* MOISTURE-VAPOR TRANSMISSION RATES (MVTR) OF ORGANIC COATINGS (GR-MIL/100 SQ IN -24 HR)

Coatings	MVTR**	
Polyurethane (3 types tested)	2.4	8.7
Silicone-Alkyd (6 types tested)	4.4	7.9
Epoxy-Anhydride	2.38	
Epoxy-Aromatic Amine	1.79	

** It should be noted that the values in table 3-7 were obtained by using carefully fabricated test films. In actual usage, a sprayed or dipped coating may contain imperfections such as pin holes, solvent entrapment, and contaminants which increase its porosity.

* Moisture Absorption Information from Design Guide Machine Design, May, 1967 Pg. 192.

3.2.5.2 High Temperature Range: The useful temperature range of conformal coatings is important. The maximum continuous service temperatures of the three basic types of conformal coatings follow:

TABLE 3-8. *USEFUL TEMPERATURE RANGE

Coating Type	Maximum Continuous Service Temp (deg F)
Epoxy (Amine or Polyimide Cure)	400 deg F
Epoxy (Phenolic Cure)	400 deg F
Epoxy Ester	300 deg F
Silicone	500 deg F
Polyurethane	250 deg F

3.2.5.3 High Insulation Resistance. Conditions of high temperature and humidity can lower the insulation resistance of the coating and increase the possibility of shorting. The comparative effects of humidity tests (performed according to MIL-E-5272) for polyurethane vs epoxy coating is summarized in table 3-9.

TABLE 3-9. **HUMIDITY VS INSULATION RESISTANCE

Coating	Sample	Insul Res Before Test (OHMS)	Insul Res After Humidity Test (OHMS)
	1	3.0×10^{12}	1.5×10^{11}
Epoxy	2	1.9×10^{12}	1.5×10^{11}
2-2.5 MIL	3	1.8×10^{12}	3.5×10^{11}
	4	1.8×10^{12}	3.0×10^{11}
	5	1.9×10^{12}	1.0×10^{11}
	Avg	2.1×10^{12}	2.1×10^{11}
	1	5.0×10^{12}	5.0×10^{11}
Polyurethane	2	3.0×10^{12}	2.0×10^{11}
0.5 MIL	3	8.0×10^{12}	6.0×10^{12}
	4	1.0×10^{13}	3.0×10^{12}
	5	5.0×10^{12}	5.0×10^{11}
	Avg	6.2×10^{12}	2.0×10^{12}

NOTE: A standard grid etched on copper-clad epoxy-glass laminate was used in tests for table 3-9.

* Table 3-8 Maximum Continuous Service temperature information from Design Guide, Machine Design, May, 1967, Pg. 180.

** Table 3-9 information from Insulation, June, 1962, Pg. 35.

3.2.6 Fungus Coating

Again using a standard grid, etched on copper clad epoxy-glass laminate, the comparative effects of humidity tests (performed according to MIL-E-5272A) for polyurethane, epoxy and silicone based coatings are summarized in table 3-10.

TABLE 3-10.* INSULATION RESISTANCE (MEG)—TEMP CYCLING AT 95 PERCENT RH

Coating Sample	No.	@ 26°C and 95% RH		@ 71°C and 95% RH		24 Hrs After Humidity T	
		24 Hrs	168 Hrs	27 Hrs	171 Hrs	Ambient	125°C
Epoxy/Polymide	1	90	110	0.5	0.5	3,500	0.5
Mod Epoxy	2	0.5	0.5	0.5	0.5	800	0.5
Epoxy	3	70,000	30,000	25	25	300,000	50
Epoxy/Polimide	4	100	80	0.5	0.5	8,000	1.0
Polyurethane	5	50,000	5,000	120	50	400,000	1,400
Epoxy	6	50	25	0.5	0.5	300	1.0
Polyurethane	7	130,000	100,000	400	380	550,000	1,200
Silicone	8	15	6,000	22	600	500,000	5,000
Epoxy/Polyurethane	9	200,000	75,000	500	550	700,000	1,800
Control (No Coat)	XX	5	0.5	1.5	0.5	400,000	4,000

3.2.6.1 Fungus Prohibitive: Because conformal coatings are organic, it is important to determine if they are fungus nutrients. Several environmental specifications are in use to verify the fungus resistance properties of materials (MIL-E-5272). A quick guide to microbial resistance of coating types is given in table 3-11.

TABLE 3-11. **RESISTANCE OF COATINGS TO MICRO-ORGANISMS

Coating	Resistance
Epoxy Amine	Good
Epoxy Polyimide	Good
Epoxy Phenol Formaldehyde	Good
Epoxy Urea Formaldehyde	Good
Polyurethane	Poor
Silicone	Good
Silicone Alkyds	Good to Poor

* Table 3-10 Information from Insulation, May, 1962, Pg. 35

** Table 3-11 Information from Machine Design, Design Guide, May, 1967, Pg. 194.

3.2.6.2 Reparability. Another important consideration is the question of whether coated electronic circuit boards can be repaired, if components are found to be defective. Circuit board coatings have been developed—mostly of the polyurethane type—which melt cleanly or volatize so that components can be removed by heat, or so that joints can be resoldered through the coating without removal of the coating. Problems in reparability of other types of coatings which cannot easily be dissolved or melted still need to be resolved.

In the E-63 Manpack Program, the effects of the humid environment were such that insulation resistance breakdown, corrosion, and fungus became a serious problem. To protect the circuit boards, an epoxy based conformal coating was applied to the circuit boards. This coating effectively prevented insulation resistance breakdown, corrosion, and fungus growth. However, the coating did make the repair of modules difficult, because of the difficulty in removing the epoxy type coating.

3.2.7 OV-1 Cockpit

The layout of the OV-1 cockpit was presented to LWL 11 Apr 67 at which time the three-phase inverter installation was discussed. LWL agreed that this was a real problem in terms of fitting necessary equipment into the cockpit. Because of this, it was necessary to obtain approval from the Mohawk Project Office to make necessary modifications.

Also discussed at this meeting were problems involved with UH-1 installation. Possibilities were discussed from the following viewpoints:

1. Possible interference between the pods and the forward doors.

2. Interference between the pod and the antler support, and the question of whether a 6-1/2 degree offset would solve the problem.

3. Pod ground clearance on hard landing.

4. Cockpit control mounting—specifically, whether an aircraft modification would be necessary.

5. Total power requirements.

6. Location of sensors in clean air (aerodynamically undisturbed).

7. Cubage and weight of pods, and their flight characteristics.

8. Vibration and shock requirements, such as the need for testing the total air frame with pods attached.

AVCOM was notified that Bell had requested an Army helicopter for use in the tests to locate the sensors in clean air. LWL was to bail it to GEOS, since Bell was being requested to perform the tests under a GEOS subcontract. System specification AMPD-5, Appendix F, was the work statement that Bell quoted to for this effort. The effort was not persued because of the high cost, and because of the uncertainity of the UH-1 tests in the program.

3.2.8 Ground Rules

Several other meetings regarding installation took place at LWL and Gruman. One meeting on 21 July 1967 established the following ground rules:

1. Reconnaisance and surveillance in real time for later intelligence analysis.

2. A flight altitude of 50-300 feet at maximum aircraft speed, day and night, two hours on station.

3. System flight configuration that looks like a normal OV-1 profile from the ground.

4. Test vehicles to be two stripped-down OV-1B's, which ultimately are to be returned to "B" configuration (One (Tail No. 59-26-27) was at Gruman at that time, ready for LWL acceptance and modification).

5. Fuel capacity limited the ability of the aircraft to meet objectives. Added fuel capacity could be provided, either in external wing stores or collapsible fuselage fuel cells, but problems arise. In the former case, because fuel lines run only to inboard wing stations, Nos. 3 and 4, (and carrying capacity is greater there) system pods would be installed at the outboard stations.

6. At stations 1 and 6, where the weight limitation is 500 pounds per station, and the Aero 15 C external store rack is used, use of the pods would need to be qualified. An estimated six months would have been a unique configuration.

7. With system pods at the inboard stations, collapsible fuel cells and pumps could have been placed in the fuselage for added capacity. Amount of capacity and the availability of suitable cells was questionable, and the added, undroppable weight in the fuselage would have changed aircraft flight characteristics, also. In view of these problems, the first test aircraft initially was to be configured for inboard station mounting of system pods, with sufficient wire looped in the wings to reach the outboard stations. Because of installation complications, the requirement was removed, and it was decided to go with the reduced range capability.

8. GEOS generated a work statement for the Gruman installation activity and specified the installation efforts in System Specifications AMPD-13 and 14, which are included in the documentation package. See para 3.6 for further installation detail.

3.3 SUBSYSTEM DESIGN

3.3.1 Pod Design

Phase IV pod design began with issuance of a Design Specification on 18 Feb 67. The Phase IV design was an evolutionary development of the design used in Phase II. Changes in system components, experience gained on Phase II pods, the possibility of deployment to Viet Nam, and differences in aircraft all led to a number of significant design changes:

1. The suspension lugs were changed from 1-inch thread size to 1-3/4-inch size in order to use components already in the Army inventory. This change was made by designing an adapter to make a transition from the 1-inch threads in the pod to the 1-3/4-inch threads in the suspension lug. The adapter displaced the pod away from the bomb rack by an additional 1-3/4-inches. (For the helicopter installation, it was necessary to make up extra-long jack screws to compensate for this added distance.) Because adapter failure would cause loss of the pods, the adapter design was proven out by a load test before the pods were flown. The

maximum adapter design load was 4900 pounds. In the test, the adapter carried a load of 11, 500 pounds without damage

2. The Aero 65A bomb rack used on the OV-1 is not compatible with the Aero 1A fuel pod, in that jack screw pods of the bomb rack bear against unreinforced skin. On Phase IV pods, supports had to be provided for the skin at the points of contact with the jack screws.

3. On Phase II pods, the joints between removable sections were sealed against weather by flat neoprene gaskets. On Phase IV pods, the flat gaskets were eliminated to permit metal-to-metal contact between sections of the pod skin, and thus minimize EMI and mechanical deflection problems. Weather tightness was maintained by lip seals at each joint.

4. To meet the requirement for jettison, the electrical connection between the pod and the wing was made so as to pull free under the dead weight of the pod. The Phase II connectors depended on dead weight to overcome pin friction in the connectors. The connector had a branched lanyard attached to the pod at one end and to each of the seven wing connectors at the other. In order to apply a pull strong enough to overcome pin friction, the branches of the lanyard were staggered in length so that full pod dead weight would be applied to each of the connectors in succession.

   To increase reliability, a different arrangement was used in Phase IV. Each set of connector halves was mounted in a plate. At jettison, the plates were forced apart by a set of compressed springs. Pod dead weight had only to apply a small force through a single lanyard to release the springs. Pin friction was overcome by the spring force. The connectors separated perfectly when the pods of System 1 were dropped in flight.

5. In Phase II, each pod was stabilized by a pair of horizontally opposed fins. For the OV-1 aircraft used in Phase IV, a different fin configuration was required. Four fins were used on each pod, located at 45 degrees to the horizontal.

6. Both Phase II and Phase IV pods were originally painted white. Phase IV pods were ultimately repainted in lusterless olive drab.

7. The major mechanical design change between phases came about as a result of the use of a stabilized antenna in Phase IV. This required the addition of a roll frame to the antenna used in Phase II. Not only was the antenna assembly increased in size, but the oscillation of the beam swept out a much larger aperture in the skin of the pod. As a result, much more of the original pod structure had to be cut away.

   Restoration of the strength lost by these excisions resulted in a center section structure quite different from that in Phase II. Because of the structural changes, it was considered that the load test results from Pod 2 of Phase II were no longer valid. Therefore, the new Pod 2 structure was load-tested by the method used in Phase II; i.e., by dropping a dummy-loaded pod. The structure passed the test without damage.

8. The original concept for mounting Phase IV detectors had been to copy Phase II; to mount the detectors in a separate housing outside the pod on the center section. The apparent advantage of such a mounting is that the end sections of the pod can be removed for maintenance without disturbing the sample and electrical lines between converters and detectors. A major objective throughout the pod design was to facilitate access and maintenance. However, Phase II experience eventually revealed the shortcomings of the center-section location; the long run of sample line between converters and detectors

caused transport delay and permitted mixing of the sample in the line. Furthermore, converted particles tended to collect on the walls of the sample line.

It became apparent that the converters had to be mounted as closely as possible to the detectors. A new design was worked out in which converters were mounted just infront of the detectors. A large duct (about 6 square inches in cross section) was installed to convey a large sample of the ambient air mass to the converters in their new location. a large cross-section was used to minimize wall effects. The duct was sealed with sponge rubber gaskets to an inlet and an outlet in the pod wall.

Making or breaking the duct joints was incidental to installation on removal of the nose section; no additional operations were required.

Flight test experience with the sample duct showed that the duct walls became contaminated and generated spurious signals. Therefore, the duct was eliminated and the converters were mounted on the pod wall, immediately adjacent to the detectors with their intake tubes protruding through the pod wall and extending beyond the boundary layer and into the free stream. The ends of the intake tubes are raked 15 degrees; that is, the leading edge is higher than the trailing edge in order to minimize water ingestion during flight through rain storms. The three intakes are staggered around the circumference of the pod so that each intake is free of the wake of the intakes upstream.

In this configuration, the intakes receive samples uncontaminated by the pod surface and line lengths are short. The only relative disadvantage is that lines have to be disconnected whenever the nose section is removed. Additional handholes were installed to allow access to the connections.

9. To keep detectors and converters close to the same temperature, as is required for good sensitivity, ambient air is taken in at the nose of the pod and exhausted at the rear of the nose section. Fans located in the air stream blow ambient air through the detectors from bottom to top.

10. To provide general cooling for Pod 1, an air intake scoop was added to the nose and an exhaust to the aft section.

Photographs of pods during various stages of modification are shown in figures 3-3 through 3-10. Figures 3-11 through 3-16 show the completed pods under weight and center of gravity test.

3.3.2 Chemical Subsystem

3.3.2.1 Detectors. The Phase IV detector program was based on essentially the same operational criteria as the Phase II design; three sensitivity ranges of 5, 20, and 50 thousand particles per cc, full scale; a fast boxcar type of output circuit, 5 volts full scale; ability to sample at either 5 or 10 samples per second; and a goal of calibration drift less than ±20 percent over a period of 75 hours operation.

Following is a summary of the initial detector requirements:

Scales Required:	5/20/50 thousand particles/cc
Scale Correspondence:	When switching between scales, the detector output signal must conform to within 20 percent of point, except for output less than 10 percent of full scale the limit shall be 2 percent of full scale.

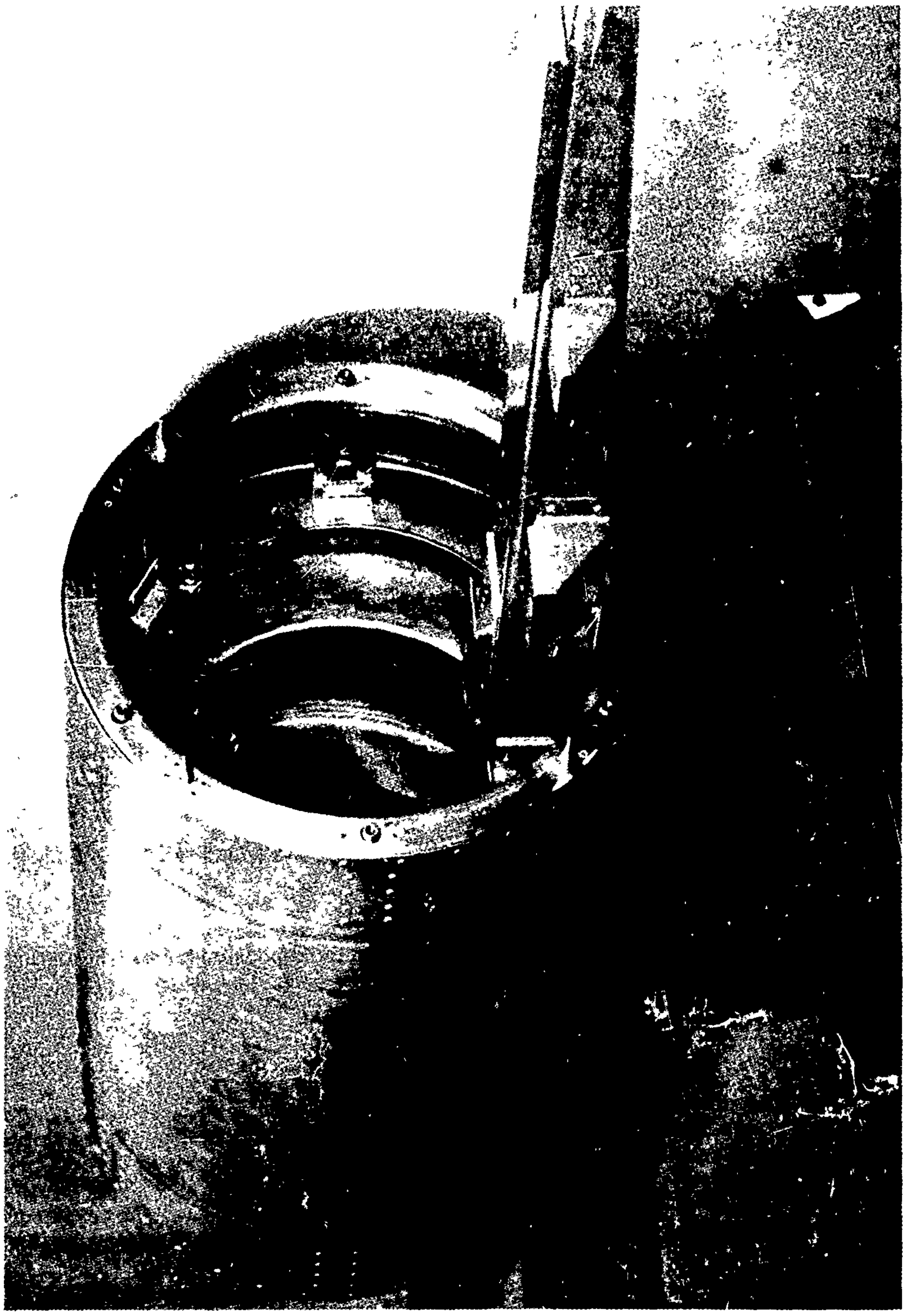


Figure 3-3. Pod 1 Center Section and Beam.

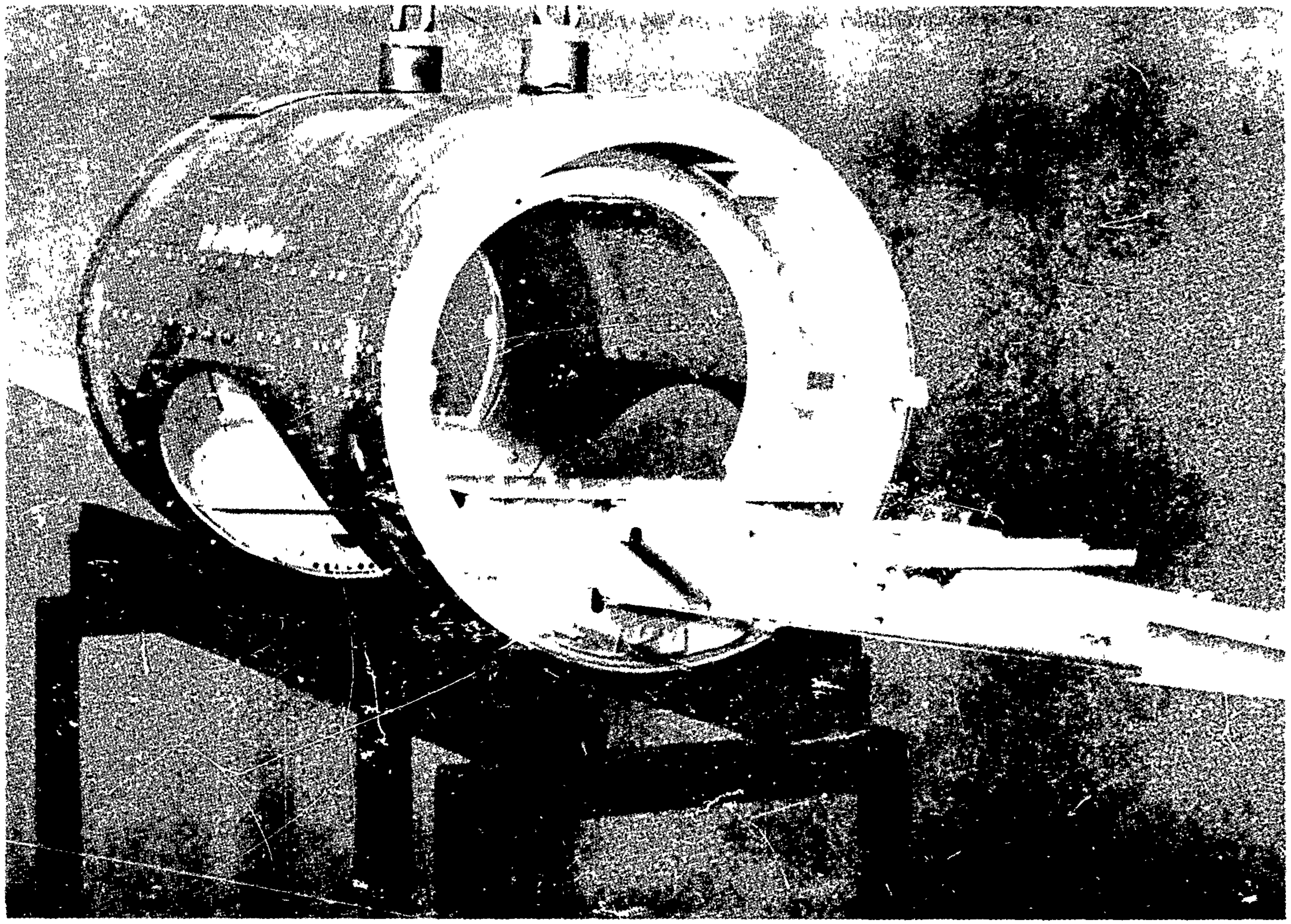


Figure 3-4. Pod 2 Center Section and Beam.

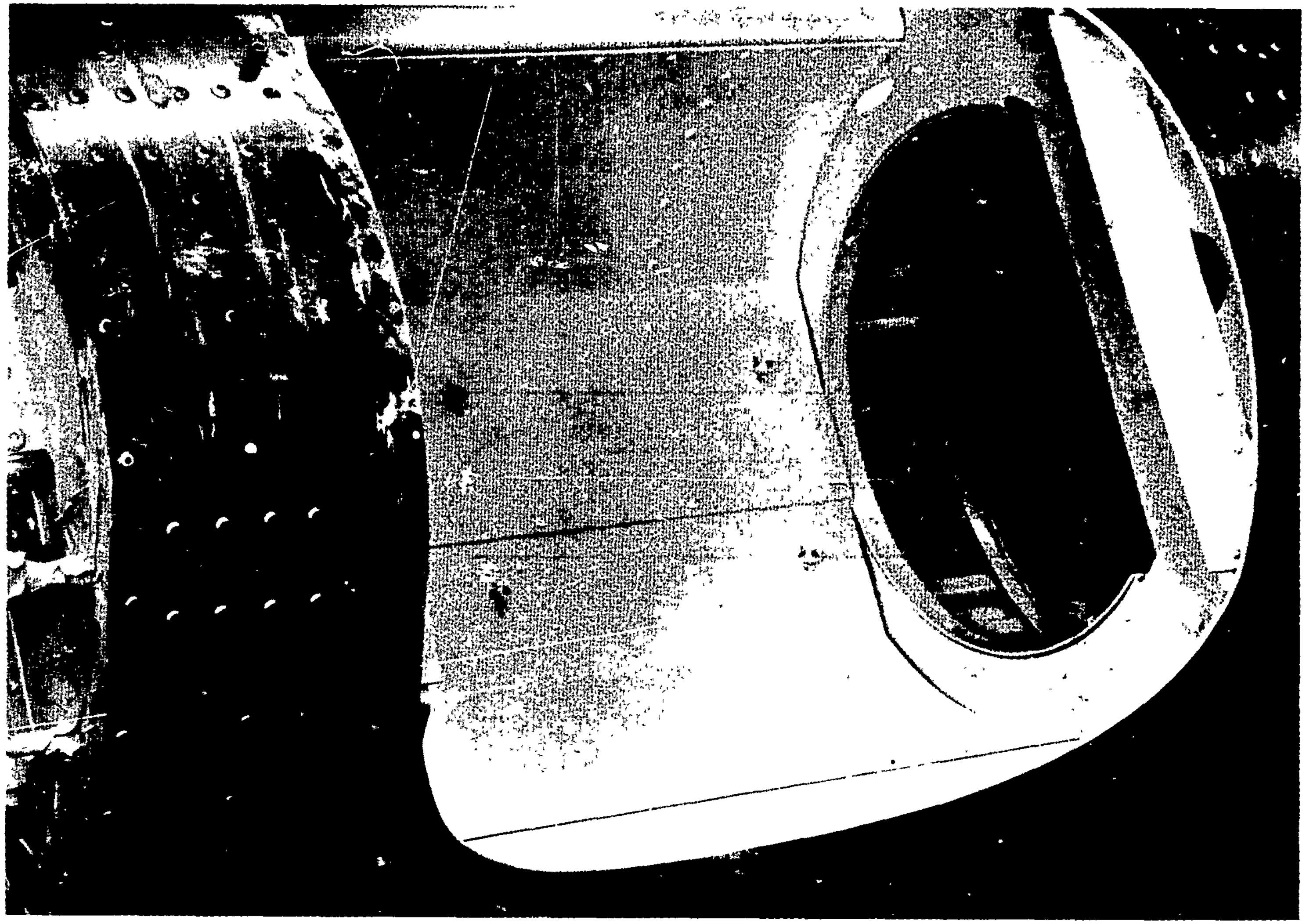


Figure 3-5. Pod 2 Center Section (Antenna Compartment).

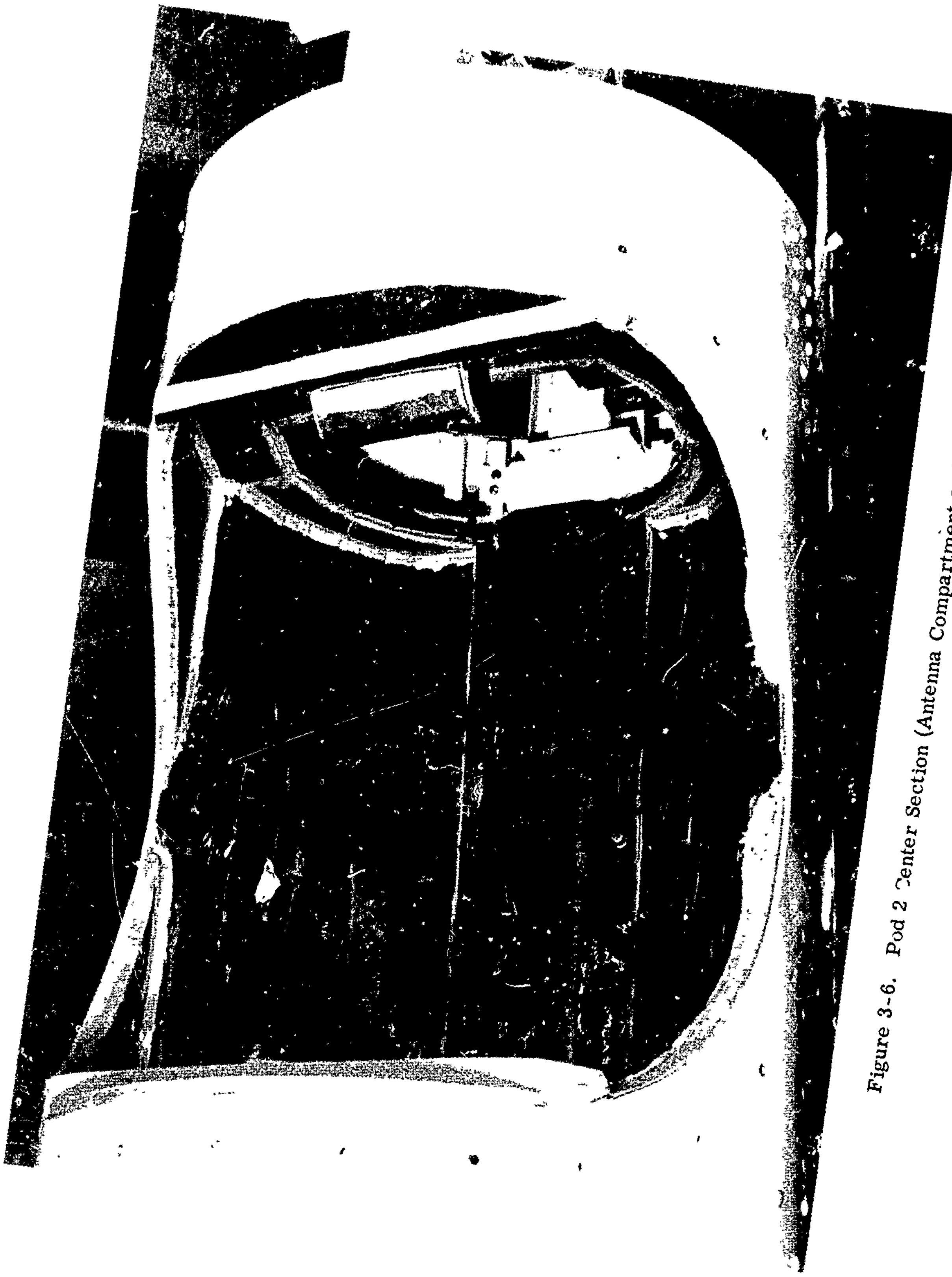


Figure 3-6. Pod 2 Center Section (Antenna Compartment and Cable Trough).

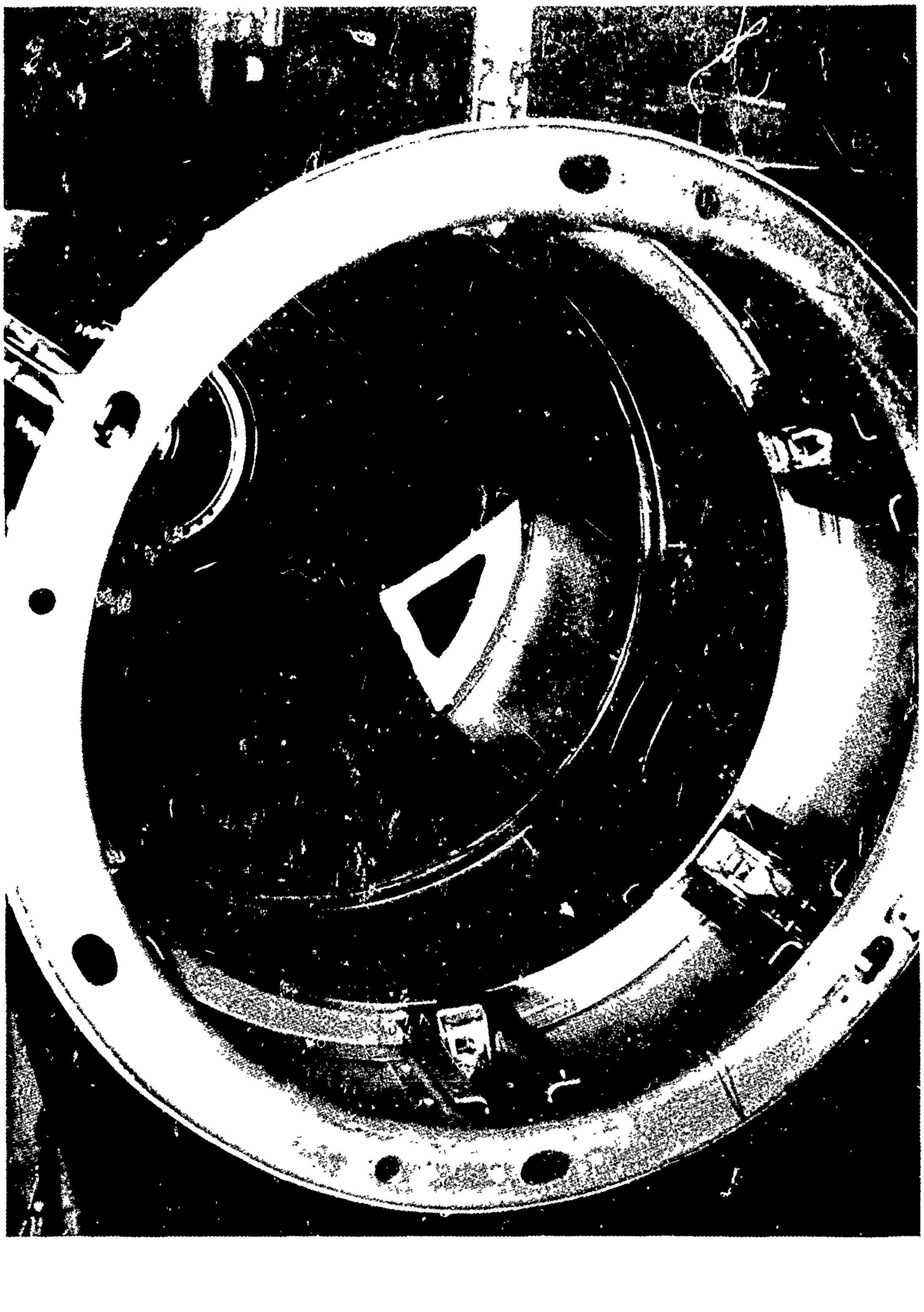


Figure 3-7. Pod 2 Forward End Section.

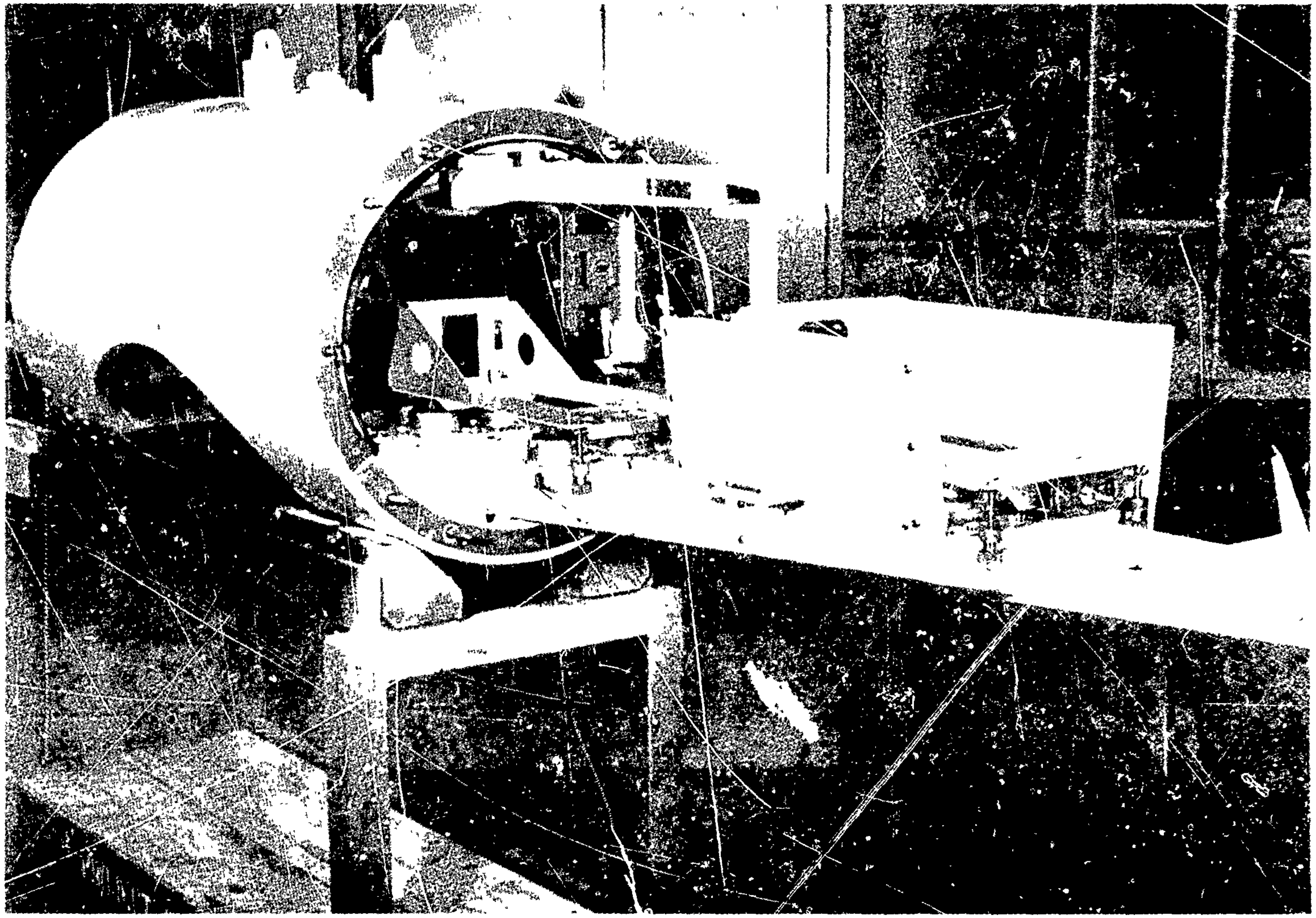


Figure 3-8. Pod 2 Aft Beam Sections With Equipment Shock Mounts Installed.

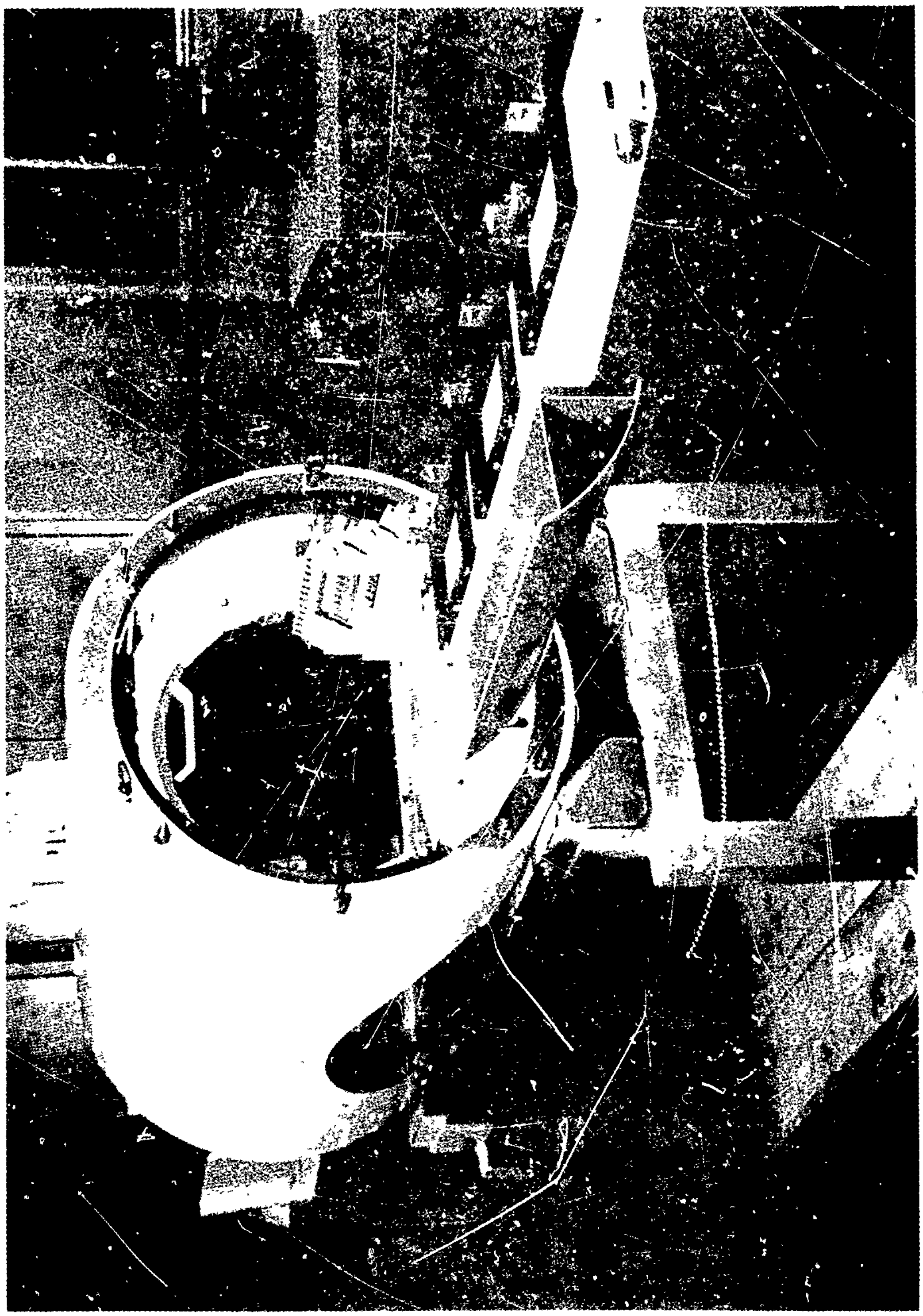


Figure 3-9. Pod 2 Forward Beam Section With Equipment Mounting Brackets Installed.

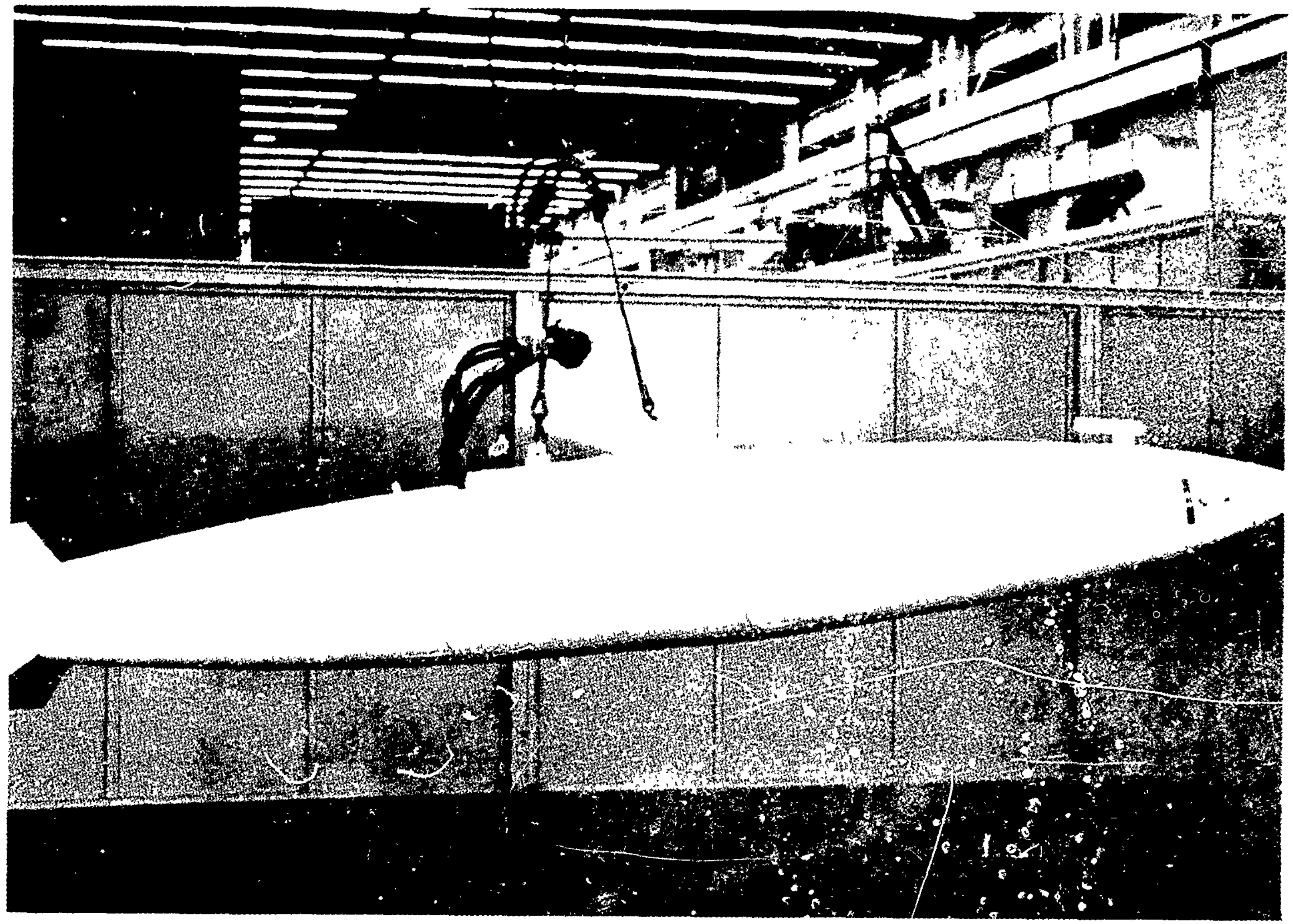


Figure 3-10. Pod 1 Weight and Center of Gravity Determination (View Right Side).

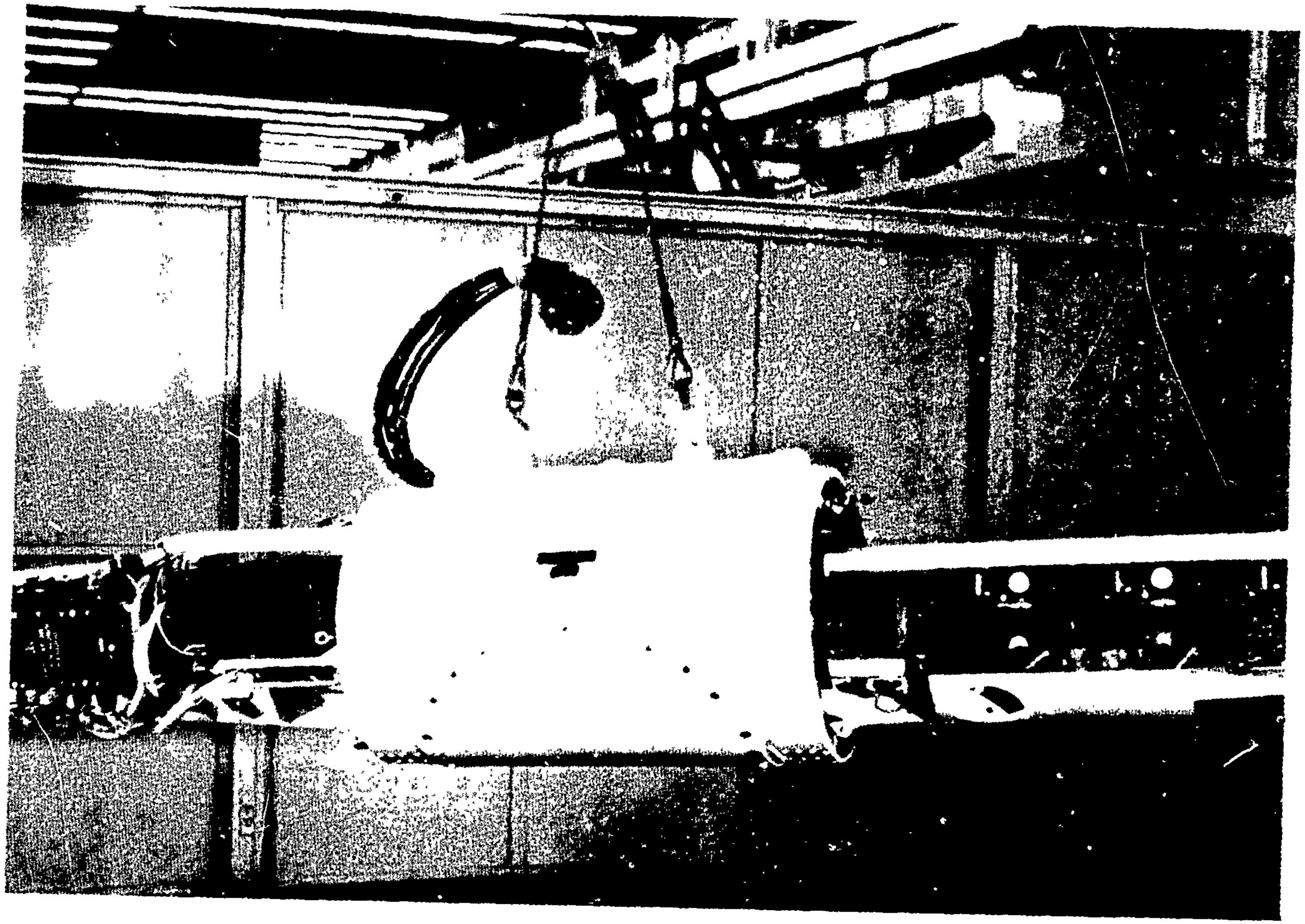


Figure 3-11. Pod 2 Weight and Center of Gravity Determination End Sections Removed (View Right Side).

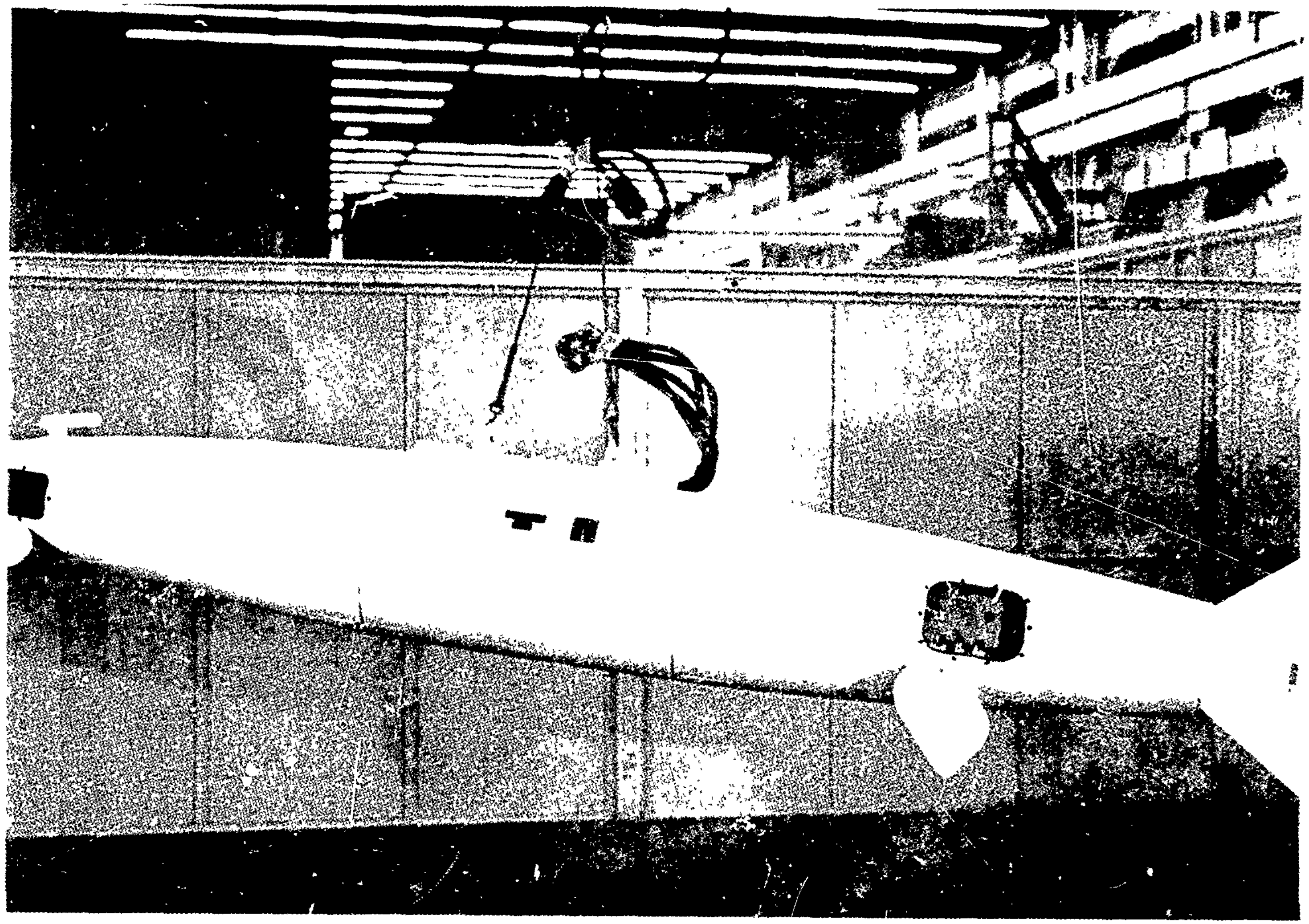


Figure 3-12. Pod 1 Weight and Center of Gravity Determination (View Left Side).

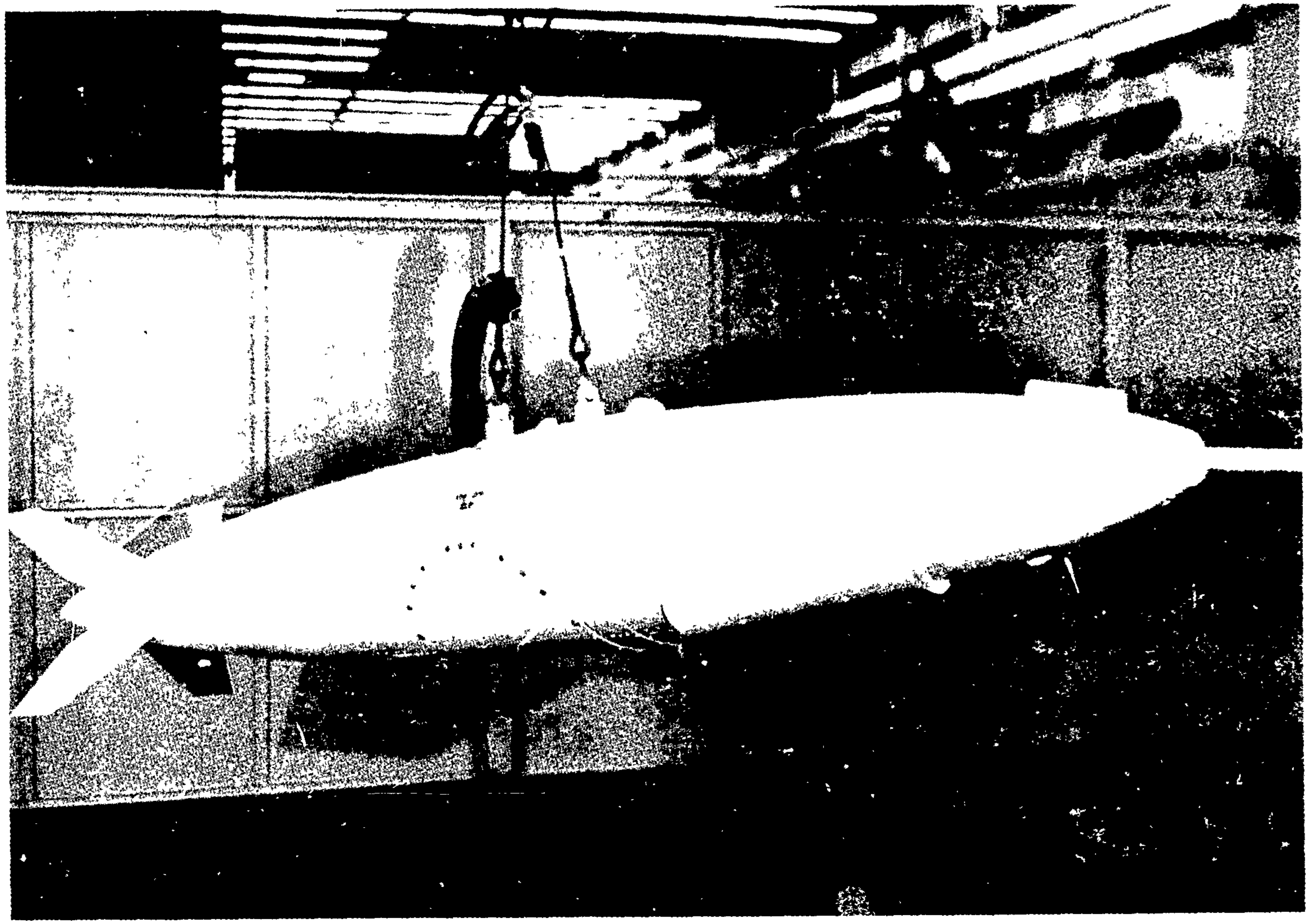


Figure 3-13. Pod 2 Weight and Center of Gravity Determination.

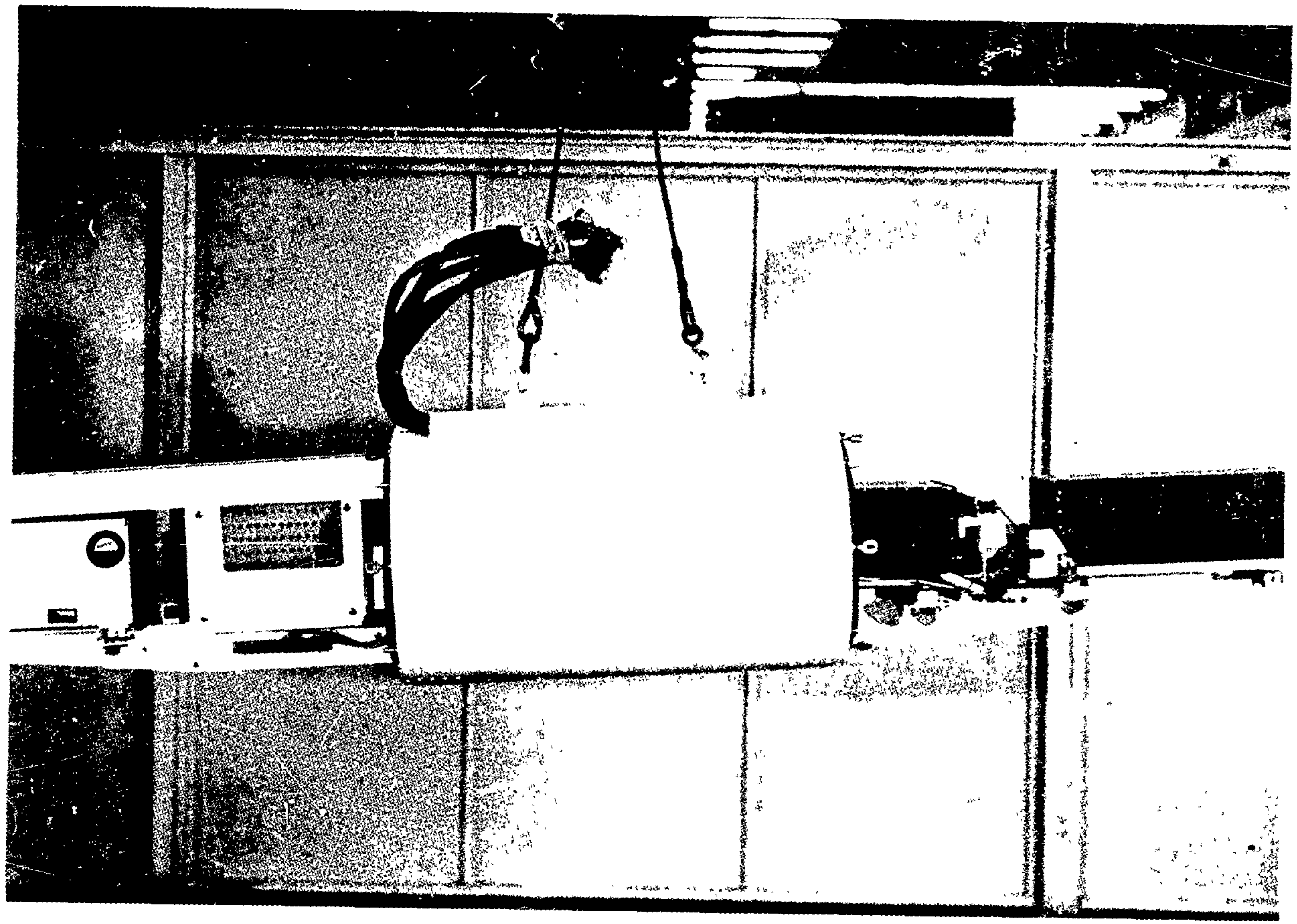


Figure 3-14. Pod 1 Weight and Center of Gravity Determination End Sections Removed (View Right Side).

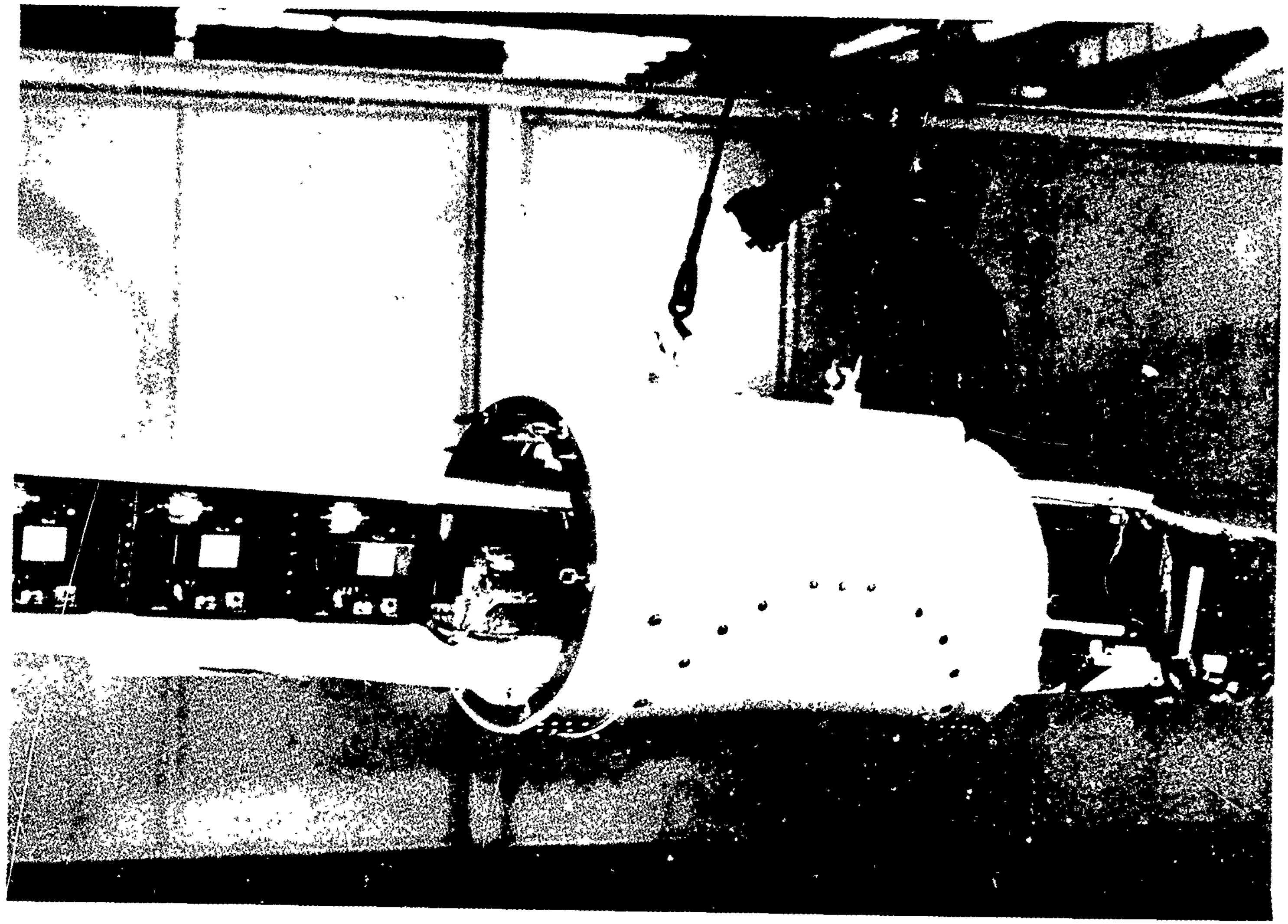


Figure 3-15. Pod 2 Weight and Center of Gravity Determination End Section Removed (View Left Side).

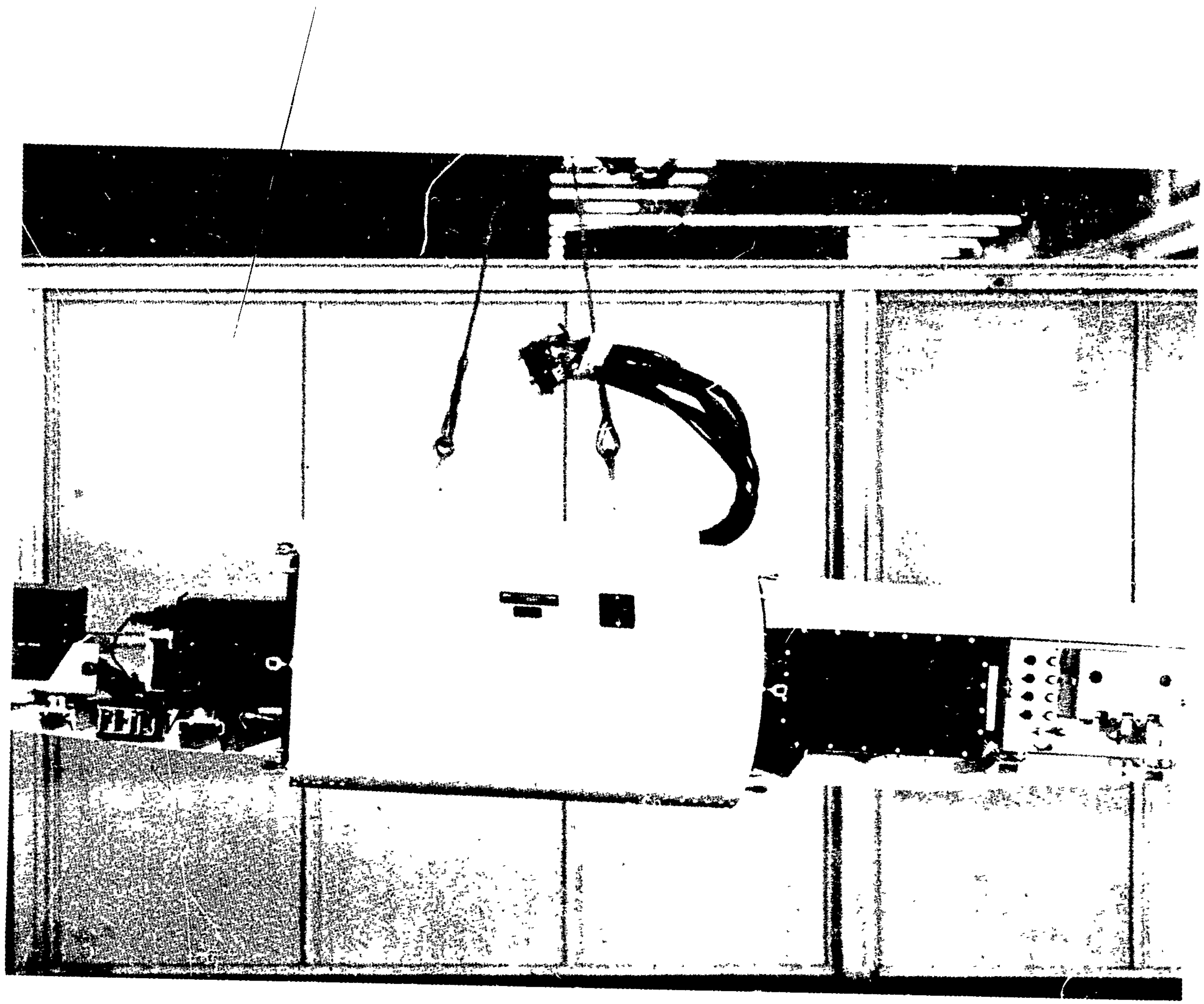


Figure 3-16. Pod 1 Weight and Center of Gravity Determination End Section Removed (View Left Side).

Output:	Zero to 5 volts dc for each scale, 3 ma maximum output current voltage limit at 6 volts ±10 percent.
Output Linearity:	Output shall be within 20 percent of point of the line drawn from 0 to the full scale output voltage except for outputs less than 10 percent of full scale the limit shall be 2 percent of full scale.
Ripple on Output:	<7 percent peak to peak of point value.
Calibration Drift:	
Design Goal:	Total drift of < 20 percent for 75 hours of operation at a CN level of 20,000 particles/cc.
Acceptable:	Total drift of < 50 percent for 75 hours of operation at a CN level of 20,000 particles/cc.
Calibration Drift Rate:	< 5 percent per hour of operation at a CN level of 20,000 particles/cc after 10 minutes of operation.
Response:	The equivalent time constant for the response of the detector to a step input shall be <0.5 second.

Because of difficulties with the Phase II detector design ascribed to the reference optical system, the chamber optical system, and the source lamp circuit, two key design approaches were directed:

1. The Phase IV detector would utilize a hollow cone optical system similar to that employed in the commercial CN counter.

2. The reference system would be eliminated, and calibration by regulation of system parameters affecting stability. Pressure contacts in the lamp circuit would be eliminated to avoid varying contact resistance problems.

3.3.2.1.1 Design Approach

1. <u>New Optical System</u>

   A mathematical study of the proposed optical system was conducted to predict optimum angles for transmitted and received light rays. In the analysis, some simplifying assumptions were made concerning scattered light intensity versus scattering angle for the droplets. The derived angles which were used were 52 degrees included angle for the illumination pattern with a dark central cone of 24 degrees included angle.

2. <u>Calibration Stability</u>

   System components whose performance would affect stability of measurement were considered as follows:

   a. Photomultiplier stability versus signal current.

   b. Source lamp light output versus operating voltage.

c. Power supply regulation and the effects of voltage variations on amplifier gain, photomultiplier gain, and source lamp output.

d. Humidifier efficiency.

3. General

General design areas for investigation and/or improvement included methods for better corrosion resistance, less valve wear, and ruggedness to resist vibration and shock.

4. Study Results

a. Tests on the photomultiplier tube (931-VA) showed that drift was strictly a function of signal current, and a maximum of 2 microamperes was specified.

b. Tests of the Welch-Allyn No. 9 lamp showed that adequate stability could be obtained at an operating voltage of 1.60 volts after a burning at 2.5 volts for one hour. A special lamp base was designed for precise centering, and flying leads were provided.

c. Specifications for the lamp, phototube, and data circuit power supplies were established. Because no catalog item would meet these specifications, Transformer Electronics Corporation developed special supplies for the application.

To provide a rugged, militarized package design, the detector mechanical components were redesigned, using a casting for the mounting base. Circuits were packaged on standard military modules used in POLARIS Fire Control and Guidance equipment. Air passages were made integral to the closed chamber assembly, and the vacuum regulator was modularized, using replaceable plastic parts for corrosion-susceptible areas. Epoxy coatings were applied to surfaces and passages exposed to the air sample.

When the first units were completed, two detectors were given a 72-hour stability test which they passed satisfactorily, except for minor valve leakage. Difficulty was experienced with the glass-filled Teflon used for valve facing; the vendor was contacted, and informed GEOS that the percent of glass fill had not been adequately specified. It was found that the material used had only 10 percent glass fill-material through 20 percent glass was ordered; the units were shipped in that state to Pittsfield, to be reworked when the new valve material arrived.

One detector was subjected to an exploratory vibration test; the only resonant problem encountered was movement of the circuit boards, which was not excessive, or damaging.

Several modifications were made to the detectors throughout the Phase IV program and are discussed in the following paragraphs; see para 2.2.8 for further details.

When the new valve facing material was received, the valves were replaced and tests conducted which did not exhibit the wear and flaking previously encountered. Later field tests with converters connected began to exhibit valve material problems caused by moisture in the valve-valve seat interface.

Laboratory tests under simulated field conditions indicated that the problem was caused by moisture loosening the bond of the Teflon film deposited on the valve seat. The solution adopted was to coat the valve seat with a bonded-on, stratified material newly developed by DuPont, cabled Teflon "S". The combination of Teflon "S" and 20 percent glassfill on the valve has proven successful, and all detectors have been so modified.

Another problem encountered was corrosion of the cloud chamber block near the porous stainless steel wick, which not only damaged the blocks, but also sealed the surface pores on the wicks, resulting in loss of humidification. An interim solution has been replacement of the original wicks (4-micron porosity) with a laminated plate structure of 40-micron porosity, plus coating of the affected block area with Plibond and installation of a thin polyethylene spacer between the wick and the Pliobond-coated surface. Experience to date has been good with this combination, aided by the adopted practice of periodically removing and washing the wick to eliminate acid build-up in the humidifier.

In the course of laboratory tests, it was found that chamber vacuum would vary with the relative timing of the valve pump. A vacuum accumulator eliminated this problem, and was added to all units.

It was also found that equipments operating at 10 samples per second became excessively warm, with deleterious effects on detection of convertibles, probably because of their dependence on water molecules. Blowers were installed in the pod systems, and the problem was eliminated.

At one point in the valve material investigation, it was attempted to remove excess acid vapors from the air sample with a molecular sieve, (Linde type AW-500). Initial tests were favorable; the acid vapors were removed without significant loss of nuclei in the sample. It was later noted, however, that in conditions of moderate or high humidity, considerable heat was liberated which destroyed convertible nuclei. Fortunately, it was found that the new metal wicks functioned very well to scrub the acid vapors from the sample, and periodic maintenance of the wicks would, therefore, yield a workable solution.

Late in the program, it was decided that a single logarithmic scale for the detector would be desirable instead of three linear switched scales. A new circuit was developed with a single logarithmic scale, 50 thousand particles per cc full scale, and has been installed in most equipments. The approach employed was to utilize the logarithmic characteristic of a diode in the feedback loop in an operational amplifier to yield a logarithmic gain characteristic. The major problem associated with this approach was the temperature dependence of the diode characteristic. A satisfactory solution was to use the base-emitter diode junction in a ua726 integrated circuit device, which maintains a constant internal temperature through internal sensing and power dissipation. See para 2.2.13 for further detail on the log amplifier modification. Figure 3-17 shows the detector assembly.

3.3.2.2 Converters. A meeting was held at R&DC on 15 Aug 67 to discuss converter design status. R&DC had Corona and Beta converter designs that were suitable for use on AMPD-224. Each design had unique features, so that inlet and outlet volume and other parameters were not similar. Converter sensitivity was discussed, and it was emphasized that some converter parameters could be critical. It was decided that a magnitude sensitivity of 1000 particles/cc for 10^{-13} gm/cc was a good goal for the converter design. Transient response data taken at GEOS on a converter and a single phase detector were discussed. The measured time constants were less than 0.5 second for each unit. This indicated that there was apparently less mixing than anticipated in the humidifier and converter chambers. These volumes resulted in larger transport delays. R&DC continued studies on transient response in order to make determinations of the transient performance of the AMPD-224 system for various plume widths.

On 15 Sept 67, R&DC was instructed to build six Corona and six Beta connecters for Project 224 Phase IV.

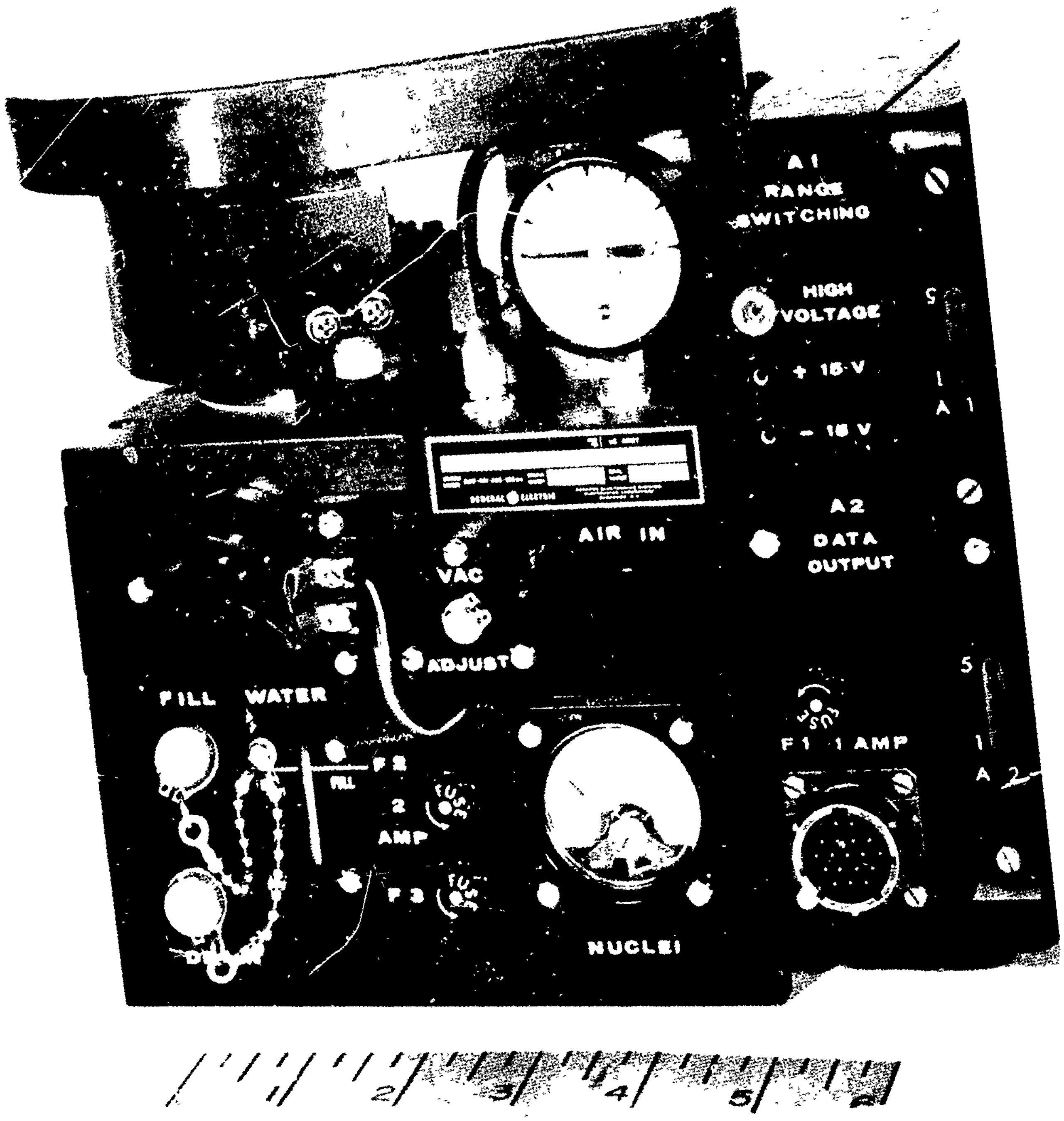


Figure 3-17. Detector Assembly.

On 27 Sept 67, a meeting was held with R&DC to discuss converter design, fabrication and safety considerations. Methods to improve system operational safety in the presence of high voltage and radiation sources were decided upon. Regarding fabrication, it was decided to treat the converter, its mounting on the air scoop, the scoop, and the associated gear (power supply, tubing, etc.) as one package. It was decided that the converters would utilize throw away HCL wicks of Dacron felt, good for 24 to 32 hours of operation. The high voltage connection would be curied in the corona converter and a high voltage warning sign affixed to it. Similarly a radiation warning was to be placed on the Beta converter, although the hazard was relatively low.

The ion source was 5.0 milicuries of Krypton 85. As a Beta source, it would have a half-life of 10.2 years. Gamma radiation at the converter surface would be less than 0.5 milliroetgen per hour.

A corona converter was received by GEOS on 4 Dec 67; it was checked out in the AMPD-224 Phase IV system during system test of the first system. A Beta converter (without a Beta source) was received by GEOS on 14 Dec 67.

During January, 1968, R&DC conducted converter tests at Homestead AFB, Florida. The results of these tests were inconclusive. However, in March, 1968, the Phase IV, AMPD-224 system was flight tested at Homestead AFB, Florida. These tests indicated that the corona converter design was definitely unsatisfactory. The Beta converter was shown to be simply ineffective. After these tests, R&DC investigated the problems associated with corona converters. As a result of this investigation, a number of determinations were reached, as follows:

1. Tests were made to determine if injected humidity would produce greater converter sensitivity. It was concluded that injected humidity would not increase converter sensitivity.

2. It was found that a temperature difference of 5°F between the detector and the converter would cause a loss of sensitivity.

3. Heaters in the converters were investigated as a possible method of decontaminating the converters and increasing sensitivity. Application of heat to the converter inlet proved to be effective in laboratory tests, but field tests did not produce good results.

4. The size of the corona points was found to have an effect on continued sensitivity of the converter. One-mil diameter corona points were shown to be more effective in maintaining converter sensitivity than 20-mil diameter corona points.

As a result of this investigation a number of changes were made to the Chemical Subsystem in the AMPD-224 system. These changes can be found in para 2.2.9 (Converter Changes and Modifications). A more detailed study of corona converter characteristics can be found in the "Personnel Detector Converter Investigations" Oct , 1968 report, of the Chemical/Biological Unit of GEOS.

3.3.2.3 Analyzer. The AMPD-224 Phase IV analyzer was developed as a redesign of the Phase II analyzer. Preliminary breadboard circuit design and component selection was started on 3 Mar 67. The initial design specification (CBDS-24) was issued on 24 Apr 67 for GEOS to design, build and test two 3-channel analyzers. Circuit design was based on R&DC schematics, with changes made only where breadboard analysis and evaluation indicated that the changes would improve performance or reliability. Packaging was designed to meet maintenance, environment, and cockpit configuration requirements in the JOVI-B aircraft.

The first one-channel breadboard design was completed on 17 Apr 67. The breadboard channel was integrated with a detector at the Electronics Laboratory in Syracuse, N.Y., on 21 Apr 67 and no major problems were found.

On 28 Apr 67, work was begun on the design and construction of a single-channel laboratory analyzer to checkout packaging and electrical design. The laboratory analyzer was completed on 9 Jun 67 and the packaging design was found to have two major problems. The coupling between the background potentiometer and the feedback motor required redesign to allow for greater shaft misalignment, and the solid wire connections between the type 2 plate pins and front panel mounted components required a redesign incorporating stranded wire and the addition of four connectors on the type 2 plate to allow for aircraft vibration effects on the wiring. These problems were corrected, and the functional checkout of the single-channel laboratory analyzer was completed on 14 Jul 67 with no further design problems apparent. As a result of the construction and checkout of the laboratory channel, the final electrical and packaging design was decided upon, and analyzer No. 1 and No. 2 chasses fabrication was started on 11 Aug 67.

On 17 Aug 67, the power supply configuration of the analyzer was changed to conform to the recommendations of a system grounding study (see para 2.2.7). The new power constraint required that the ±15 vdc power in the analyzer be isolated from power ground in the AMPD-224 system. The design specification (CBDS-24A) was issued on 21 Sep 67 and the new power supply modules were completed and checked out on 15 Oct 67.

The first 3-channel analyzer (No. 1) was completed on 6 Oct 67 and a functional checkout indicated that all functions operated properly. On 1 Nov 67, analyzer No. 1 was vibration-tested.

The analyzer was vibrated while in an OFF condition. The vibration strength was as follows:

Trial 1: A five-minute sweep of the following ranges:

5-10Hz	double amplitude 0.08 inch
10-15Hz	±0.42 G's
15-70Hz	double amplitude 0.018 inch
70-500Hz	±3.0 G's

The analyzer was structurally complete and this trial produced obvious resonances within the analyzer.

To determine the source and strength of the vibration, a second vibration run was made with the vibration strength as follows:

Trial 2: A ten-minute sweep of the following ranges:

5-10Hz	±1.0G
10-15Hz	±1.0G
15-70Hz	±1.0G
70-500Hz	±1.0G

The analyzer was not structurally complete during this run because the side panel on the module side was removed for observation of component vibration.

During this run, a strobe was employed to visually detect any vibrations. It was noted that at different frequencies, individual modules vibrated with G forces as high as 20G. Wiring vibrated only slightly, even though it was not tied down to the chassis. No excessive vibration was detected on the front panel, motor mount plate, or any of the associated wiring.

After this test, the analyzer was tested to determine its status. Everything functioned without problems, with the exception of the pot-motor linkages (couplings). The coupling tended to bind. Apparently some shift had occurred between the shafts of the motor and the potentiometer. The couplings were removed and more play was machined into the coupling, and the problem of binding was fixed. With this correction, the analyzer ran without any appreciable deviation from previbration data.

The SN No. 1 analyzer was integrated into System 1 and checked out with the system during system test. For checkout data see para 3. 5 (System Test).

On 20 Nov 67, it was decided to build a third analyzer. Parts were ordered and module procurement and chassis fabrication started.

The SN No. 2 analyzer was completed on 9 Jan 68 and it was checked out in the system during system test. No major problems were found.

For further changes to the analyzer portion of the Chemical Subsystem, see para 2. 2. 17 (Analyzer Changes) and para 3. 5 (System Test).

3.3.3 Navigational Subsystem

The navigational subsystem is a modified Doppler Navigation Set (AN/ASN-64) and consists of two subsystems, Navigational Doppler (AN/APN-168) Subsystem and Navigator Computer (AN/AYA-3) Subsystem. The navigational doppler subsystem is made up of an RF antenna, a receiver/transmitter, a frequency tracker, and an altimeter. The navigational doppler subsystem makes use of the doppler principle to measure aircraft groundspeed and altitude. Both of these signals are transmitted to the data handling subsystem for use in source location prediction. This subsystem also generates true track, antenna drift angle, and subsystem timing signals that are used in the navigator computer subsystem function.

The navigator computer subsystem provides a continuous record of aircraft position and local wind components, and provides the control and display function for the total navigational subsystems.

The AN/ASN-64 Navigator was developed on CMC funds and has been in production for the U.S. Army. The AN/ASN-64 was ordered from Canadian Marconi Company, a directed source, on 21 Mar 68. They were ordered to system specification AMPD-1.

A GEOS representative went to Montreal on 3 Jul 67 to witness final test on the first AN/ASN-64 system. The test utilized a dummy antenna and no junction boxes.

To expedite delivery, the following items were hand-carried from CMC on 20 Jul 67:

Item	S/N	Qty
Junction Box, Computer and Doppler	--	1
Receiver—Transmitter	102	1
Frequency Tracker, S/N	335/336	2
Dummy Gimbals	--	1
Waveguide Assy	--	1
Indicator, Velocity Steering	336/337	2
Indicator, Altitude	103	1
Antenna	335	1
Computer, Navigational	102	1

A control indicator was required to complete the system for bench testing. This item was stopped in CMC Quality Control. It was delivered on 17 Aug 68.

Stabilizing gimbals were delivered at a later date along with servo amplifiers.

CMC submitted statistics describing the expected accuracy of the navigator, representing performance based on experience.

Under ideal conditions (well-swung compass, much adjustment, accurate knowledge of magnetic variation) the navigational accuracy (including SR-3 compass errors) is:

σ in track = 0.3 degree
σ in ground speed = 0.3 percent

These computations assume a compass transmitter compensated to 12 minutes peak and a 12-minute measurement error. Therefore, the track error goal of 0.75 degree mentioned by the Instrument Department still seems applicable for field conditions.

The position error quoted was:

$2\sigma = 0.2$ percent of distance traveled when range > 10 miles.

Because the error in range varies inversely as the square root of range, the expression to be used for ranges shorter than 10 miles is:

$2\sigma = 0.632\,(\text{range})^{-1/2}$ percent of distance traveled when range < 10 miles.

The error should be normally distributed for short ranges. An error of 0.5 degree was quoted for the synchro outputs and is primarily due to gearing errors. On the 160 km/rev output, this amounts to 220 meters.

The position errors experienced during the C-47 Everglades flight tests were discussed. Errors of 200 to 700 meters were mentioned as typical after 20 to 30 minutes of flight with many turns. It was CMC's position that the use of a stabilized antenna would reduce these errors by one-third, or to about 200 meters, because much experience has shown that restricting the bank angle of the aircraft does not reduce navigation error since smaller errors exist for longer periods of time. The major source of error in an unstabilized configuration is the fact that the aircraft is rolled about the true airspeed vector rather than the ground speed vector. This results in an error in measured drift angle since this is no longer measured in a horizontal plane with the results of an incorrect resolution of ground speed into north and east components.

CMC indicated that large errors (± 25 percent) should be expected in the computation of wind in the navigation computer, due to the fact that wind is computed as the difference between two large vectors, ground speed and true airspeed. Estimates of the accuracy with which components of these vectors are measured are:

Ground Velocity	-	0.2 percent
Drift Angle	-	0.2 degrees
True Airspeed Direction	-	2.0 degrees
True Airspeed Velocity	-	5 percent

The major error sources are true airspeed direction and velocity. The direction error is primarily uncompensated yaw of the aircraft. CMC indicated that flight tests have shown that a pilot cannot trim an aircraft for yaw to better than 2 degrees. There is very little feedback to indicate yaw to the pilot. The true airspeed (TAS) velocity error is due to the Kollsman TAS transmitter design and pressure measurement error. The error in TAS velocity could probably be reduced by redesign of the TAS transmitter.

The doppler navigator can be used to measure wind directly if the aircraft is flown in a circle at constant airspeed. Then, the azimuth at which the doppler drift angle goes through zero is the direction of the wind, and the peak-to-peak-amplitude in ground speed is twice the wind velocity, assuming a constant wind velocity over the measurement period. Accuracy estimates of one knot and 2 degrees were given for this method.

The time constant for the wind servos is one second in the fast mode; this has normally been used for slewing the wind solution. The wind solution circuitry was modified at GEOS and is discussed in para 2. 2. 5.

3.3.3.1 Stabilized Antenna. The small antenna has been found to give the same accuracy as the large one. Therefore, only the small antenna was considered for stabilization. The fact that the pitch and roll synchros on the SR-3 gimbals are excited from Phase A of the compass represents a problem that can be solved in the navigator. A reference signal must be provided with these signals.

Space is provided in the frequency tracker enclosure to mount the electronic boards for the pitch and roll gimbal servos.

A stabilized antenna is required in a helicopter for automatic hovering control. For the unstabilized antenna, the navigator will not switch to memory mode until the bank angle becomes greater than 60 degrees.

3.3.3.2 Interfaces. CMC was planning to provide a linear electrical output covering the range 0 to 2500 feet rather than 0 to 1000 feet, as requested. This would produce a quantization step size of 39 feet per count in the digital converter. Two linear ranges of 0 to 500 feet at the original quantization of 15. 6 feet per count and 500 to 2500 feet at 62. 5 feet per count was specified.

CMC had planned to disconnect the wind outputs to the velocity steering indicator and to provide the 12-volt outputs of the wind potentiometers to GEOS. They were asked to excite the wind potentiometers from the 5-volt reference and to connect the VSI indicators back in the circuit. With the wind switch on the VSI in the wind set position, a continual wind output indication is provided. The VSI meters have 25 μamp movements.

3.3.3.3 Position Repeaters. Several position repeaters are available, but CMC did not recommend them. An accurate stepper motor repeater is the same size as the control indicator (it is provided in the same case, but with the unneeded functions removed). A small inaccurate repeater that operates from the synchro outputs has excessive gearing error. Position errors of 800 to 900 meters were quoted for this unit, and include the errors in the synchro outputs.

During the month of March, 1967, it became clear that several interface problems were developing between the plotter and the navigator. As a result, a meeting was held at Canadian Marconi, Montreal on 3 Apr 67 with CMC, GEOS, and Loral in attendance. The following document records the agreement reached at that time.

SUBJECT: ASN-64 NAVIGATION SET - LORAL PLOTTER INTERFACE

COPY

DATE: APRIL 3, 1967

The following is the agreement among The Canadian Marconi Company, The Loral Electronics Corporation and The General Electric Company as to the interface between the ASN-64 Navigation Set and the Loral Plotter for The Project 224 application of the two equipments:

1.0 Interlock from Plotting Board Line:

The plotter shall transmit + 28 VDC to the Navigator when it is in the Run mode. The plotter shall supply an open circuit when in OFF and STBY modes.

2.0 Interlock to Plotting Board Line:

The Navigator shall supply the +28 VDC reference to the plotter for only the ON Line signal in para 1.0.

3.0 EW Present Position Slew Direction to P/B Line:

The Navigator shall be an open circuit (+28 VDC) for East or Ground for West when the Run mode. In STBY or OFF modes, this line shall be an open circuit.

4.0 EW Present Position Slew Direction from P/B Line:

The Plotter shall return the EW Direction Sense signal to the Navigator except when the Plotter is in East slew when an open circuit shall be transmitted or when in Plotter West Slew in which case a ground is transmitted.

5.0 EW Present Position Slew (Slow) Line:

The Plotter shall transmit to the Navigator a ground on either a East or West signal. Otherwise an open circuit is transmitted.

6.0 EW Presnet Position Slew (Fast) Line:

The Plotter shall transmit to the Navigator a ground on either an East or West fast slew signal and maintain a ground on EW Slow Slew Line. Otherwise an open circuit is transmitted.

7.0 In the STBY mode, the signals in para. 5.0 and 6.0 are blocked in the Navigator.

COPY

COPY

8.0 EW 1/100 KM Pulses Line:

The Navigator shall transmit to the Plotter pulses at a rate not to exceed 350 pulses per second. Each pulse shall represent 0.01 KM of distance. The pulses shall be 6$\pm$ 1 volts in amplitude referenced to ground -0, +0.5V and 0.5 to 1.0 milliseconds in width. The input impedance at the Plotter shall not be less than (Ohms) resistive. Noise level shall be less than 0.5 volts with respect to signal ground. The signal shall be transmitted on a shielded wire. The shield shall be grounded at the Navigator only.

9.0 NS Signal Lines:

All lines specified in para. 3.0 through 8.0 shall be repeated for North - South Signals where East is replaced with North and West is replaced with South.

10.0 Common Ground:

Three 22 AWG wires shall run between the Navigator and the Plotter.

H. FIEDLER	M. FERENCZY	A. M. VAN BLARCOM
G. ROCK	R. ANTENEN	G. PREHMUS
A. LEHRER		R. W. KENYON
FOR LORAL ELECTRONICS	FOR CANADIAN MARCONI	FOR GENERAL ELECTRIC COMPANY

COPY

3.3.3.4 Navigator Maintenance. Modifications to the antenna roll frame pedestal feet and design of the waveguide assembly by CMC required coordination efforts during the Spring of 1967, to ensure that the waveguide assembly and the roll frame fitted the pod antenna cavity. The cavity was lined with ecosorb material to prevent false antenna lock-on within the pod structure. A minimum amount of refitting was required when the materials were received.

The Doppler Navigator Subsystem was the major maintenance problem throughout the program. Following installation of the navigator in the pod during August and September, 1967, a Canadian Marconi field representative spent several days each month working with a GEOS navigator technician to maintain the navigator. These CMC field representative services were required each month from October, 1967 through June, 1968 (except April and May, 1968 when the van was on its way back from Homestead, Florida).

Therefore, the following recommendations were submitted for the support of the modified AN/ASN-64 Doppler Navigation Set for overseas operations.

1. Provide complete spare/repair parts—both sniffer unique and standard.

2. Provide a complete set of test equipment to support maintenance, alignment, and equipment surveillance.

3. Assume that field service personnel will perform all maintenance, alignment, and equipment surveillance on the Doppler Navigation Set.

4. Procure modified Janus Oscillator Boards (in frequency tracker) prior to overseas deployment.

5. Deployment be delayed until field support is assured. Otherwise, the lack of critical spare parts could cause delay of the AMPD-224 evaluation.

These recommendations were based on the following CMC inputs:

1. Army support vans are at Vung Tau.

   a. The Army unit where all Mohawk electronic equipment is checked for operability. No repairs are performed in it. A "few" G.I.'s operate this van.

   b. A General Support Van operated by one CMC technical representative and two CMC technicians.

This Van (1b) had supported a number of aircraft as of October, 1967, and more had been added since that time. Another CMC technical representative was available for training and other general support activities as required.

2. A report to CMC, Montreal, indicated a large backlog of units to be repaired. This is due primarily to lack of spare parts. Other problems include lack of test equipment due to slow turn around time for the repair of this equipment and space limitations.

3. Three areas in RVN were supported by CMC-operated general support vans. A 29 Feb 68 report stated that of the total aircraft mounted Doppler Navigators in RVN, approximately 10 percent of the total aircraft (Doppler Sets) were down for repairs.

Dependence on in-place maintenance personnel and spare/repair parts places a high risk on maintaining continuous Doppler Operation in RVN.

To provide further spares for the navigational computer, a memory storage unit and a delay multiar and buffer board were purchased from Canadian Marconi. These components were incorporated into the Phase I computer along with other changes to update it to the Phase IV configuration. At the same time, the Phase II computer was updated to the Phase IV configuration so that all navigational computers are interchangeable. This helped the maintenance problem somewhat.

Modifications to the wind computer and track resolver drive were made at GEOS to give a more accurate wind solution. A differential synchro was added to the true airspeed transmitter output for the same reason. (Details in para 2.2.5). Special alignment and checkout procedures were developed for field and lab testing of the new configuration. These procedures had been supplied to the field and are also contained in the Operation and Maintenance Manual.

To eliminate the possibility of errors and/or damage to the navigation system due to antenna oscillating in pitch, roll, and/or drift, the respective servo amplifiers in the frequency tracker had to be adjusted.

Each time a Frequency Tracker was installed into the system the Antenna was checked and adjustment made if the Antenna were oscillating. Procedures were developed to check for this adjustment and were inserted in the manual.

The electronic memory storage units supplied with the navigational computers were not interchangeable because of impedance mismatching. GEOS redesigned the input circuit to prevent the mismatch. Field Service made the modification so that the units are now interchangeable.

NOTE: (See FBDs 7 and 8 and the Operational and Maintenance Manual for complete functional description of the Navigational Subsystem.)

3.3.4 Compass Subsystem

The compass subsystem consists of a Sperry compass transmitter, and an attitude heading reference set, the AN/ASN-76 (SR-3). In addition, the navigational antenna roll frame is considered to be a functional portion of this subsystem, although it was actually purchased with the navigator. The AN/ASN-76 was purchased from a directed source, (GE West Lynn), and was ordered on 17 Mar 67. The system was developed on Company funds and is in production for both the Army and the Air Force.

The compass transmitter (part no. 1775277) or flux valve with the compensator was ordered from Sperry on 22 Mar 67. This unit is the same as that used in the normal OV-1 installation. The first unit was received 10 Jul 67.

Sperry is the major supplier of compass transmitters to the Army and Air Force. Transmitters of the accuracy desired for our system are selected from the Instrument Department production.

Screws on the compass transmitter control small magnets to provide up to 14 degrees of correction for single cycle error.

Twenty-four potentiometers are used to provide an additional 3.5 degrees of correction capability at points 15 degrees apart in azimuth. Access to these potentiometers is required during the calibration process. An optical transfer is required to the compass transmitter in the pod.

GE/ID was not able to recommend a three phase solid-state inverter to run the compass. The pitch and roll synchros on the gimbals that can be used as the reference to stabilize the navigator antenna are excited from Phase A of the compass inverter. Measured power requirement data was received, as follows:

	Start		Run	
Phase	Watts	PF	Watts	PF
A	28	0.61	34.5	0.70
B	35	0.76	34.5	0.81
C	48	0.76	34.5	0.70

A breakout cable at the coupler with standard instruments can be used for maintenance rather than the Army test set. Connectors for the cables to interconnect the compass components are not provided with the compass.

The SR-3 compass is now designed so that the heading loop is opened for lateral accelerations greater than 0.065 g. Therefore, the free gyro drift data applies under this condition. Roll erection is closed at a rate of 1.25 degrees/minute for all conditions. Pitch erection is normally 5 degrees/minute, but is reduced to 1.25 degrees/minute for fore and aft accelerations of 0.065 g.

The Sperry C-12 compass that is on the NU-8F is a 2-axis gyro rather than a 3-gimbal platform like the SR-3. Therefore, it has greater errors in indicated azimuth during turns. Canadian Marconi Company advised that there is no electronic compensation in the NU-8F compass.

The AN/ASN-76 system was received 12 May 67, and was the first subsystem to operate in the laboratory. The total compass subsystem performed reliably throughout the program, with the only failure being due to human error in the laboratory.

There was initial concern for operation of the compass transmitter within the pod environment, because surrounding metal and nearby d-c currents could effect accuracy. It was not until the compass was swung that it was realized that accuracy would not be a problem. The favorable results are reported in paragraph 3.9.

(See FBD 10 for functional detail on the compass subsystem.)

3.3.5 Meterological Subsystem

The initial question involving the meterological subsystem in Phase IV was whether a turbulence sensor (as used in Phase II) or an accelerometer would be employed in the system. Turbulence measurement was made with an MRI unit, which also measured temperature. However, this unit was sensitive to vibration, and the reliability of the turbulence output was questionable because of this sensitivity. The vibration problem was discussed with MRI on 25 Apr 67. The main problem in the MRI design was lack of support for the circuit boards. MRI was already aware of the problem, and had started a redesign.

During May, 1967, it was decided to cancel the Phase IV order for the MRI meteorological equipment. It was planned that a new temperature measuring unit would be bought, and a test package of accelerometer, filter, and breadboard amplifier would be developed. The accelerometer package would be delivered to R&DC for tests on the NU-8F aircraft, to determine accelerometer vs. MRI turbulence sensor correlation.

The accelerometer package was completed and sent to R&DC on 16 Jun 67. Rosemount Engineering temperature sensors/amplifiers were chosen on 27 Jun 67 to replace the cancelled MRI temperature measuring equipment.

The tests run by R&DC on the turbulence sensor vs the accelerometer were inconclusive. R&DC was in favor of returning to the MRI turbulence/temperature unit. On 2 Aug 67 it was decided to cancel the Rosemount Engineering order for a new temperature sensor and reinstate the order for the MRI turbulence/temperature unit.

The first MRI unit was received on 4 Dec 67. The unit was checked out, and the packaging was modified to provide better support for the printed circuit board.

On 2 Feb 68, the MRI unit was installed in system No. 1 (during laboratory checkout) and checked out. The data follows:

Turbulence: Digital readout increased with propeller acceleration, and decays exponentially to zero.

The turbulence meter in the system test panel operated properly.

Temperature: With an ambient temperature of 60.8 deg F, the digital readout of temperature was 60.93 deg F, well within the desired system accuracy.

The temperature meter in the system test panel operated properly.

The MRI equipment was found to have a problem with the turbulence propeller during field testing. For a discussion of this problem see para 2.2.12 (Turbulence Propeller).

3.3.6 Plotter Subsystem

One of the early system requirements was for a graphical display to provide a visual display of the aircraft's position over the ground and to mark points of special interest. A plotter which would display a map of the area and automatically plot the aircraft's position was needed. The requirement for marking points of interest (not necessarily at the aircraft's present position) was of major importance. The plotter should also provide for flexible modes of operation. Some points of consideration included ease of changing displayed maps; capability to change from one mapped area to another; capability of using various map scales; ability to mark special symbols upon command at commanded offset positions, and size and weight.

The two vendors considered were Loral Electronics and Avion. The Avion plotter used a strip-chart that was driven to provide plotting in one direction. Plotting in the other direction was accomplished by moving the pen. The strip chart required special preparation, and therefore somewhat restricted the operational areas because of the lead time required to prepare charts. Also, there was no provision for offsetting from the present position or providing special marks.

The Loral plotter was only in a developmental stage. It was designed to use map sections mounted on boards which provided coded information about the map section to the plotters logic. It also provided for a choice of map scales, extended operational area beyond the displayed area, and special symbols at offset positions. The map boards and area concept provided the flexibility needed for moving from one area to another because standard maps could be cut and mounted on the easily recoded boards in a minimum of time. The vendor was also willing to incorporate modifications.

On 28 Feb 67, a purchase order was issued for the Loral plotter with scheduled delivery dates for three units of June 1, July 3, and August 1, 1967. Loral's product specification PS-322 Revision B is included as an Appendix B of this report.

The first unit was delivered 31 Aug 67. The delay was the result of the addition of several modifications as well as other developmental and scheduling problems. After delivery, there was a period in which a number of failures and other problems (some requiring modifications to the plotter) occurred. Since this initial period, the plotters have operated satisfactorily.

The following sections of the plotter subsystem report consist of discussions covering; the development of design requirements and inclusion of modifications; human factors involvement with the plotter and map preparation, and the initial period during which a number of problems occurred.

3.3.6.1 Design Considerations.

3.3.6.1.1 Plotter Review. On 6 Oct 66 a meeting was held to review the revised specification for the Loral plotter, to further define the interfaces with this unit, and to discuss possible changes to the basic plotter for the Phase IV systems. Loral had prepared a revised copy of the TND-4 Map Plotter Specification. Pertinent topics that were discussed are listed as follows:

1. Simultaneous Plotter and Navigator Updating. Loral and Marconi agreed to a method that permits simultaneous updating of both the plotter and navigator position data from either the plotter or navigator slew switches, with the plotter in the ON state. Initial synchronization of the navigator and the plotter to the geographic grid must be done individually. The plotter must be in the STBY state during this process.

2. Plotter Slew. The plotter can be slewed in only one cardinal direction (North/South or East/West) at a time.

3. Pen Mechanism. The pen mechanism and the plotter controls were designed as part of the lower unmovable section of the plotter display assembly. Whenever the cover is raised, the pen is lifted and moves to the upper left corner to keep it out of the way. The map holder tilts up to allow insertion of map boards. The pen itself was to be a small nylon cartridge type made by Estabrook, not refillable, and should be replaced after every flight. It should draw at least 300 inches of line. The time to change the pen was quoted as 20 seconds with a special tool.

4. Pen-Lift Command. Loral was to design the plotter to accept a pen-lift command and to inform GE of the requirements for this command signal. This was to be used as the event marker symbol.

5. Environment, Mounting, Connectors. Storage at a temperature of 100 deg C is no problem. The computer unit could be hard-mounted. Loral was to send an outline drawing of the computer unit.

The plotter display assembly was to be designed to mount on standard Dzus rails 11.5 inches apart. Loral recommended a slant mounting angle suitable for writing and permitted changing the map boards. Connector information was to be provided by Loral to R&DC.

6. Maps. It was not possible to cut the maps to provide overlap. It was pointed out by Loral that by establishing a different 0/0 point the maps could be cut to center one area of interest on the display.

   The plotter was designed to operate without manual reset in an area of 200 km x 200 km.

7. Off-Course Commands. Both an off-course command and a symbol command must be received simultaneously to obtain an off-course plot or an on-course symbol plot that was planned for trace broadening. Loral was to advise GEOS if an 18.5 μ s delay between the commands was acceptable.

The plotter was designed so that it would not hang up if multiple commands were received due to unexpected operating conditions. Thus, if more than one symbol command is generated, it will respond to the first one recognized and ignore the others. If an off-course command is received before a previous off-course cycle is completed, it will be ignored. An event or lift-pen command during an off-course plot was to lift the pen, and therefore the plot would not be made.

Loral was to inform GEOS of the minimum time between symbol commands with zero offset. (This was required to properly control trace broadening).

The situation of a present aircraft position off the map with an off-course command that would place the plotted position on the map was discussed. The plotter was hung up whenever the aircraft position was off the map, and the plot was not made.

8. Cover Open Indication. Loral agreed to provide a cover-open signal to the computer in order to block off-course commands in this situation. They were to specify to GEOS whether this would be a contact closure or logic level.

9. Five-Minute Time Mark. The requirement to make a five minute timing mark was deleted.

10. Phase IV Plotter Changes. Loral was asked to prepare a preliminary proposal to indicate how the following features could be added to their basic plotter.

    a. Overlap

       Can the map index number counters be designed so that maps at a scale of 1/250,000 and smaller are cut with overlap?

    b. Straight Line Off-Course Marking

       How can the computer unit be designed to provide straight line marking to an off-course position? Further use of the general purpose digital computer should be considered.

c. Larger Area of Operation Without Reset

How can the area of operation (200 km x 200 km) best be increased? Two alternatives are to increase the area defined by the MIN counters to (1000 km x 1000 km), or to have these counters change automatically between states 0 and 19.

d. No Symbol Command

How can the plotter be designed so that it can accept an offset command to draw just the lines but no symbol?

11. Map Handling and Preparation Equipment. Loral pointed out that there was no effort at present on map preparation equipment and procedures and on map handling equipment.

3.3.6.1.2 Plotter Design. A meeting was held 5 Jan 67 to further discuss the design of the Loral plotter. The following was discussed:

1. Plotter Mounting Angle. The plotter could be mounted at any angle between the horizontal and vertical but clearance was to be provided to remove the map boards.

2. Cabling Information for R&DC. Loral agreed to send cabling information to R&DC on 10 Jun 67. GEOS was to buy the connectors for the cables.

3. Phase 2 Delivery. It was estimated that delivery of the Phase II plotter would slip by six weeks.

4. Pen Lift Command. A Loral engineer was to check the logic levels of the pen-lift command and inform GEOS.

5. Memory Converter Mounting. The memory converter unit (formerly the plotter computer) could be hardmounted, although the drawing showed a shockmount. The mounting bracket without the shockmounts could be used in a hardmount situation.

6. Outline Drawings. Loral provided outline drawings of the plotter head and the memory converter.

7. Cover Open Indication. Loral was to provide a logic level as a cover open indication. The signals were to be 5 volts with the cover open and 0 volts (or ground) with the cover closed.

8. Plotter Specifications. The preliminary plotter specification that was received from Loral on 6 Oct 66 was to be revised by Loral to include the agreements reached since that meeting; and furnished to GEOS for use as a procurement specification. The copy of the specification that Loral brought with them was identical to the October 6 document.

9. Simultaneous Plotter and Navigator Updating. The interface between the navigator and plotter was reviewed briefly. It was found that the control indicator must be used to put the navigator in the update mode in order for the plotter slew switch to provide update commands to the navigator.

10. Signal Ground. Loral agreed not to connect their signal ground to chassis ground. Instead several No. 24 conductors were to be run out to Pod 1 where a single connection of signal ground to chassis ground was to be made for the system.

11. Design Improvements

a. Map Overlap

A discussion of map overlap indicated a general agreement that it was required, with a divergence of opinion as to how to accomplish it. Loral had estimated that a 10-week redesign effort would be required. In a discussion with Loral of a scheme based on using the present MIN grid points as possible map origins, Loral indicated this might provide a simpler solution. Loral was to provide GEOS with a quote on the cost and schedule of providing the Phase IV plotter with this feature.

b. Bearing Line

Loral could modify the plotter to draw a bearing line to the commanded offset point. In order to do this they need the present analog voltages for the offset plus a 7-bit digital offset command. They estimated a 6-week redesign effort for this feature.

c. Extended Area of Coverage

In response to the GEOS request for extended area of coverage, Loral recommended that the MIN grid be extended from the present coverage of 0-19 to 0-99. This would increase the area of coverage without reset to 1,000 kilometers on a side.

d. No Symbol Command

The requirement to draw a bearing line without a symbol at the offset position presented no problem. Loral estimated a two-week redesign effort.

e. Re-packaging for Design Improvements

Design improvements a, b, and c required a larger memory converter enclosure. This was to be a A1C box which was 3 inches longer than the enclosure shown on the outline drawing furnished.

f. Map Storage Concept

Loral presented a map storage concept based on a loose-leaf map storage envelope scheme that exposed the edge of each map on which the MIN identification number would be shown. Additional effort was required in this area to come up with a good concept for the Phase IV systems. Loral was to provide a quotation on their present concept by February 15.

12. Plotter Installation. Loral did some work to investigate the problem of installing their plotter in the OV-1 aircraft. In particular, they talked with the OV-1 project officer at AMC, safety people at Ft. Rucker, and with Grumman. They showed a possible arrangement of the plotter installed on rails between the pilot and co-pilot. Their opinion was that the OV-1 represented a difficult installation problem because of the crowding in the cockpit, and that helicopter mounting was a simpler problem.

13. Quoting Procedure. A GEOS purchasing representative discussed briefly with Loral the procedure for quoting the three Phase IV plotters to GEOS. Loral indicated that they need a $25,000 commitment within 10 days in order to keep their present precision machine part vendors on the job for the Phase 4 plotters. They were to send a TWX to GEOS Purchasing confirming this.

The GEOS delivery requirements as presented to Loral were one unit by May 1; one unit by June 1, and one unit by August 1. Map storage units, if ordered, would be required as one unit by August 15, and one unit by October 1.

Loral was working in order to be in a quoting position by January 20. They were to provide quotes for the basic plotter as developed for Phase II, plus a quote for each of the design improvements. They were to quote engineering support during installation and a per diem rate for field maintenance support.

14. Documentation. Loral was planning to provide installation and outline drawings plus the specification. They were asked to also quote on providing operation and maintenance information and agreed to quote this by March 15.

15. Spares. Loral was asked to recommend spare parts required for one year of operation. They were to quote this by March 15.

16. Operating Supplies

    a. Map Boards

    Loral was buying four map boards which they would supply with the plotter. GEOS was to ask for a quote on the number of boards desired. These boards were precision-machined to meet the plotter accuracy specification. The maps were glued to the map boards with rubber cement. They were then covered with military acetate (Scotch Magic Tape in 9 inch rolls). This tape was to be ordered through a jobber who cuts larger rolls into 9-inch widths. Markings on the acetate could be washed off with water.

    b. Pens

    Loral had ordered 100 pens from Estabrook and they were to supply whatever number is left after their test program. GEOS was to order additional pens which were to be identified by a Loral part number.

3.3.6.1.3 Plotter Design Improvements. A Loral representative called on January 6 to transmit the following information on the requested design improvements. He confirmed this by telegram.

1. MAP OVERLAP. Maps at scales of 1/100,000 and smaller could be cut to provide overlap by using all MIN grid points as possible map origins. The current design permitted this, and no redesign was necessary. Therefore, only the 1/50,000 maps could have no overlap.

2. BEARING LINE. The plotter could be modified to draw a bearing line to a commanded offset point. An estimated 4 to 6 weeks design time was required. Loral wanted authorization to proceed with the design effort prior to the contract in order to meet our delivery schedule.

3. EXTENDED AREA OF COVERAGE. To extend the area of coverage, an additional 3 bits of memory were needed for each MIN axis. This added memory presented a schedule problem. However, they were to quote the change and indicate the schedule effects.

4. NO SYMBOL COMMAND. Represented no problem.

5. PEN-LIFT COMMAND. The pen-lift command would be brought out to GEOS on one line so that grounding this line will lift the pen.

6. COVER OPEN INDICATION. The Cover Open indication would be +4 volts. When the cover is closed, it was 0 volts.

7. MAP SCALE CODE. The map scale code outputs are tabulated as follows:

Scales	Code
1:50,000	010
1:100,000	110
1:250,000	001
1:500,000	101
1:1,000,000	111

8. OFF-COURSE COMMANDS. The delay of 18.5 usec between an off-course command and a symbol command was acceptable.

The plotter would not hang up if multi-commands are received, rather it would execute the first command it received and ignore any command after the first command.

9. SYMBOL COMMANDS. After the first symbol command is received any subsequent symbol command the plotter receives will be performed whether the first symbol command is finished or not.

3.3.6.1.4 During a meeting on 18 Jan 67 the following was discussed:

1. Map Mounting Boards. The Loral drawing of the map mounting board was discussed. The tolerance shown for the code holes appeared overly tight and was to be checked. The hole coding was not yet specified. Loral proposed to drill all holes and plug those not desired with wooden pegs. The holes were to be read by mechanical switching means. Loral considered doubling the board thickness (1/16-inch to 1/8-inch), to ease the manufacturing problem of the board guides in the plotter head. GEOS objected and Loral was to reconsider.

Maps can be mounted on both sides of the map boards. GEOS Engineering was to investigate the advisability of GEOS making these boards.

2. Slew Speed. A GEOS Human Factors representative indicated that the slow speed slew rate was too high for accurate positioning of the plotter pen. He was to consider this further and call Loral to reach an agreement by 19 Jan 1967.

3. Mark Pushbutton. The specification called for the mark pushbutton on the plotter to make a 1/4-inch square. Loral was to check to see if this was correct and inform GEOS. (Note: This was verified).

4. Cover Open and Map Scale Factor Outputs. Loral engineering was to inform GEOS Computer Applications of the need for isolating diodes in these outputs.

5. Map Overlap. The method of cutting maps with overlap at scales of 1/100,000 and smaller was reviewed. This required no change to the plotter design.

6. Bearing Line. Loral needed a digital command to draw a bearing line to an offset point. They were to quote this as an additional modification to the present plotter design.

7. Extended Area of Coverage. Loral could provide extended coverage by cycling the MIN counters between the 00 and 19 states. They were to quote this as a modification to the present plotter design.

8. No Symbol Command. Loral could provide the means to draw a bearing line with no symbol at the end. They were to quote this as a modification to the present plotter design.

9. Present Plotter Specification. The specification for the current plotter design was reviewed and resulted in several of the above items. Loral was to provide a quote to GEOS for a plotter to this design by 23 Jan 67. At the same time, they would quote the requested modifications 6, 7, and 8.

10. Map Storage. GEOS Human Factors was to consider the proposed approach to map storage and inform Loral of the GEOS position. Based on an agreement, Loral was to quote on their approach by 15 Feb 67.

11. OV-1 Installation. Loral was to send to GEOS a diagram for a possible installation of the plotter in an OV-1 Mohawk aircraft.

3.3.6.1.5 TELECON 24 JAN 67. A Loral representative telephoned 24 Jan 67 to provide the following information:

1. Map Mounting Boards

   a. The specification on the locating holes was 3/32" diameter, drill through (no tolerance on fraction).

   b. The print showing scribed lines for locating maps on boards was in error and was being revised.

2. Loral was issuing an updated Product Specification.

3. The Phase IV Plotter quote was going out on this day.

3.3.6.1.6 Coordination Meeting. Human Factor representative visited Loral 16 Mar 67 to coordinate the engineering efforts and to survey Loral's facilities.

Discussed were:

1. Doppler/TND-4 Interface. An apparent lack of communications or a misunderstanding between Loral and Canadian Marconi Company had resulted in an interface problem in the following areas:

   a. Loral did not anticipate a relay to drop the plotter out for navigator updating.

   b. Twenty-four volts was required on the direction line in the open condition.

   c. CMC required four lines for slew speed. Loral indicated the fix could be incorporated in phase IV plotters with no delivery delay.

2. Map Board Coding. It was requested that shouldered plastic plugs rather than the match stick technique be developed for coding map boards. The shouldered plugs would require minor modifications to the plotter to allow map board clearance. The approach was being evaluated by Loral.

3. Map Storage—Scaler Mix. Loral proposed a technique of mixing map scales on a preselected basis that offered a greater degree of versatility than was previously available. Loral was to submit the plan in detail as a part of their Phase IV quote.

3.3.6.1.7 MEETING 3 APR 67. A meeting was held 3 Apr 67 at Canadian Marconi with Loral GEOS, and R&DC representatives present. The interface signals between the Loral plotter and the ASN-64 navigator were specified as follows:

1. Interlock from Plotting Board Line: The plotter shall transmit +28-vdc to the navigator when it is in the RUN mode. The plotter shall supply an open circuit when in OFF and STBY modes.

2. Interlock to Plotting Board Line: The navigator shall supply the +28-vdc reference to the plotter for only the signal in paragraph 1.

3. EW Present Position Slew Direction to P/B Line: The navigator shall be an open circuit (+28 vdc) for East or Ground for West when in the RUN mode. In STBY or OFF modes, this line shall be an open circuit.

4. EW Present Position Slew Direction from P/B Line: The plotter shall return the EW Present Position Slew Direction to P/B signal to the navigator except when the plotter is in East slew, when an open circuit shall be transmitted; or when the plotter is in West slew, in which case a ground is transmitted.

5. EW Present Position Slew (Slow) Line: The plotter shall transmit to the navigator a ground on either an East or West signal. Otherwise, an open circuit is transmitted.

6. EW Present Position Slew (Fast) Line: The plotter shall transmit to the navigator a ground on either an East or West fast slew signal and maintain a ground on EW Present Position Slew (Slow) Line. Otherwise, an open circuit is transmitted.

   In the STBY mode, the signals in para 5 and para 6 are blocked in the navigator.

7. EW 1/100 KM Pulses Line: The navigator shall transmit to the plotter pulses at a rate not to exceed 350 pps. Each pulse shall represent 0.01 KM of distance. The pulses shall be 6 ± 1 volts in amplitude referenced to ground -0, +0.5 volts and 0.5 to 1.0 milliseconds in width. The input impedance at the plotter shall not be less than 900 ohms resistive. Noise level shall be less than 0.5 volt with respect to signal ground. The signal shall be transmitted on a shielded wire. The shield shall be grounded at the navigator only.

8. NS Signal Lines: All lines specified in paras 3 through 8 shall be repeated for North—South Signals, where East is replaced with North, and West is replaced with South.

9. Common Ground: Three 22 AWG wires shall run between the Navigator and the Plotter.

3.3.6.1.8 MEETING 21 APR 67. An R&DC representative visited Loral 21 Apr 67 to check on the status of the plotter and to become acquainted with the unit.

The status of the plotter equipment was stated by Loral to be as follows: The computer unit was completed except as noted following. Changes in wiring had been made so the power input was to the computer unit instead of to the plotter head as originally planned. There were still several problems to be dealt with in the plotter head. Loral was finding it difficult to achieve motion of the pen as fast as called for in the specifications. Specifications stated that an off-course command will be held by the computer for five seconds. On the 50,000:1 scale, this could mean that the pen could be required to travel all the way across the plotter diagonally in 5 seconds. This could be done (with difficulty), but it would take five additional seconds for the pen to get back to the original point, during which time no second off-source-command would be issued without causing a malfunction. Loral was to contact GEOS about this.

A print was obtained from Loral containing wiring information needed by R&DC to prepare the wiring harness, and the latest changes so that GEOS could then proceed with the cabling.

The plotter head has been so constructed that when the lid was opened, the pen automatically moved off-scale. R&DC indicated that this was unfortunate, because it prevents writing by the operator on the maps while a run is in progress, without possible loss of data.

The Off-Course Mark Time was further discussed with a GEOS Human Factors representative who noted that Loral PS/332, (page 7, para 2.6 Appendix B), specifies that "...the plotter will, upon receipt of the proper command and symbol pulses and off course target data, cause the bug to leave its present position, while continuing to trace, and mark an off course target and then return to the updated present position in 5 seconds maximum". This requirement means that the bug must travel diagonally (in steps) completely across the map board, make an off-course target mark, and return to its starting point in 5 seconds.

The Loral Project Engineer pointed out that commercially available stepping motors are not, under load, capable of the 125 pps required to meet the 5-second time limit. He stated that under ideal conditions they could approach 5 seconds, but that it represented the upper limit of the motors and drive system and suggested that the speed vs reliability trade-off might not be in the best interest of the system.

At Loral's request, the 5-second time limit was reviewed by C/B Detection Equipment Engineering and, upon receipt of a request for deviation from Loral, the specification was changed from 5 seconds maximum to 10 seconds maximum. The request for deviation will spell out a 5-second capability which will be an off-course mark one-half the diagonal distance across the map board.

When the Phase II plotter was delivered to R&DC, it exhibited certain erratic operations. The source of the problem was traced to a ground loop that was created within the plotter (this problem is covered in para 2.2.1 of this report).

3.3.6.1.9 MEETING 17 JUL 67. A meeting was held on 17 Jul 67 to further discuss Phase IV interface requirements of the plotter.

A Loral representative restated his position in regard to any future problems that may develop with the plotter. It was agreed that Loral would start working on a solution to a problem if GEOS were to give a firm indication that immediate action is needed. The cost impact needed to be considered when the problem was discussed with Loral, but the paper work wouldn't be necessary before Loral could act on the problem.

A GEOS Engineering representative attended briefly to discuss shielding of the plotter lines. A Loral engineer said that shielded would not be necessary. It was agreed that shielding would be used as specified by GEOS Engineering.

Discussion of the plotter-navigator isolation circuit was extensive. It was discovered that the output from the CMC navigator was not as expected. It was then decided that the circuit being prepared by GEOS Circuits Engineering was not as desirable as an operational amplifier circuit. An operational amplifier was constructed by GEOS and tested by Loral; the amplifier operated as expected; a Loral representative was in Schenectady 18 Jul 67 to incorporate it into the Phase II plotter.

Loral still expected to be able to ship the first Phase IV plotter on 1 Aug 67; the isolation problem was not completely resolved by that time. The plotter provided for inclusion of the isolation circuit. This provision was such that a circuit board was exchanged causing negligible interruption of our schedule.

The Phase IV plotter head and power supply were finished, and work began on the digital section.

When the first plotter was received (31 Aug 67), it was exercised and tested extensively during which time some problems were isolated. The list of problems became formalized and issued as "Electrical/Mechanical Problem Areas Associated with the Loral Plotter—TND-4," which follows. Several design problems became evident as some of these problems (following) were investigated. The major ones were numbers 2—Voltage Spikes, 3—Off Map, and 8—Transient Sensitivity. These design problems are covered in section 2.2.1 of this report. It was also considered that the step size was undesirable.

ELECTRICAL/MECHANICAL PROBLEM AREAS ASSOCIATED WITH LORAL PLOTTER—TND-4

1. Off Course Target (refer to PS322 para 2.9 and 3.2 Appendix B).

   If off course target coordinates are set-up on the plotter's display lines, the plotter responds to them without a command. It also seems to receive the same information when moving in either "X" or "Y" and also adds the signals together to form a target. As a result X = Y displacement in all cases. The plotter will not return to present position unless the coordinate voltages are removed.

   To initiate the above actions, the plotter must receive a number of navigator pulses, an off course command, or a "Mark" command.

2. Voltage Spikes

   The voltage spikes caused by the plotters power supply should be minimized. There does not seem to be any part of PS322 that can be referred to for this problem. This problem is considered to be serious enough that something should definitely be done to minimize the spikes. The plotter's immunity to transients should improve and it will be possible to identify the sources of transients which are not masked by the spikes.

3. Off Map

   If the plotter is driven off the top or bottom border of a map section, and the cover is opened, the bug will remain in the corner when the cover is reclosed. But if the bug is driven off the right or left border and the same thing is done, the bug will run down the edge to the "Y" coordinate and stop. PS322 para 1.4 (as amended on 3-8-67) only requires the bug to stay at a border. The action should be the same for both "X" and "Y" off map conditions although it is not specifically covered in PS322.

4. Slew Speed

The bug slew speed does not meet PS322 para 1.2 per modification D which gives it as 1.4 in/sec in fast slew and 0.17 in/sec in slow slew. The speeds were measured as 0.33 in/sec in fast slew and 0.26 in/sec in slow slew. Also, if the bug is slewed off the top or bottom border, the plotter slews the MII at a very rapid rate. If the bug is slewed off the other borders, the slew continues at the same rate.

5. Map Frame

If a map board is left out of the map frame, the bar on the map frame will depress some of the coding switches thereby giving illegal signals to the plotter causing it to malfunction. Refer to PS322 para 1.3. Operation without a map board is convenient for making some checks during set-up or testing.

6. Track-Up

The plotter malfunctions in both east-up and west-up (refer to PS322 para 2.4).

7. Mechanical

The display head that we have continues to "glitch" at times. This will sometimes cause the defective symbol pattern.

8. Transient Sensitivity

Transients within the plotter will sometimes trigger a "Mark" or top-up cycle to run. There are a number of sources of transients in our system which will cause these cycles. It is not clear as yet whether the plotter is overly sensitive to transients nor what the other sources of transients are. It has been impossible to trace transients nor what the other masked by spikes caused by the plotter's power supply.

9. Vibration Environment

The acceptable vibration environment for the plotter needs more definition. Loral has indicated that all frequencies below 40 cps should be suppressed, but has not given any indication as to the amount of supression needed. A brochure published by Loral indicates that the plotter meets MIL-E-5422, curve IV vibration. This requires varification from Loral.

NOTE

Note that some of the above comments were erroneous as the result of a poor understanding of the plotters operation. This was true for items 3 and 6. Other items required specification clarification (items 4 and 5); others repair of failed components (item 1), or adjustment (item 4). This list was revised as required when other problems occurred.

3.3.6.1.10 Step Size. Concern about the large steps (1/16-inch) that the plotter makes resulted in the issuance of a request for quote on system specification AMPD-12 "Modification to Plotter—Reduced Step Size", included in this report as Appendix E. Loral was to consider the following points:

1. Modify the three TND-4 Plotters to produce a smaller step than the current 1/16-inch step. Ideally the step should be as small as possible; however a

trade-off should be made to determine how reduction in step size effects speed of the bug to make off-course plots.

2. Modify the three TND-4 plotters to incorporate analog servo drive motors to obtain a smooth plot.

Loral was to indicate the time required to make the modifications to each unit, as well as the cost involved. It was decided that this modification was too costly, and would cause excessive delay to the project.

3.3.6.1.11 Vibration Testing. There had been concern over the operation of the system components in a vibrating environment (for example, aircraft). All of the Phase II components were tested except for the plotter. However, the plotter (Phase II) was reported to be operating satisfactorily in the C-47. When it became clear that the second system was to be tested on a UH1D helicopter, operation of the plotter under vibration was of concern.

Loral contacted Grumman Aircraft on 20 Nov 67, and indicated the following:

Loral Electronic Systems contacted Mr. M. Pepe of Grumman Aircraft Engineering Corporation regarding the vibration environment in the cockpit of the OV-1 Aircraft. He revealed the following information in terms of vibration levels versus flight profile:

Cruise/Loiter	23-25 Hz at 1.3g's
Cruise	70-75 Hz at 1.3g's
Takeoff	18-23 Hz at 1.3g's
Landing	18-23 Hz at 1.3g's
Shock	12 g's at 0.005 -0.001 secc .d

It was emphasized that the preceeding data was based upon analysis, not measurement, and that it applied to the pilot portion of the cockpit.

If assuming the above vibration and shock data was typical of what the TND-4 would see when mounted in the instrument panel, Loral felt that the TND-4 display head could be hard mounted. GEOS believed that the total effect of this environment would be some pen-skipping during the writing of off-course, target symbols and. (to a smaller extent) during the normal navigational tracking mode.

Regarding the installation of the TND-4 Memory Converter, GEOS recommended one inch clearance on each of the four sides of the unit for sway space, in accordance with MIL-C-172.

The following request for quote was then issued—the indicated guide vibration levels being based on the test conditions to which other equipment had tested.

REQUEST FOR QUOTE

Would you please request Loral Electronic Systems to submit a quote for conducting an explanatory vibration test on a TND-4 Plotter. Request Loral to submit a detailed test procedure. The test procedure is to be submitted, for GEOS approval, as part of the quote.

Items that GEOS requires to be included in the test procedure are the following:

1. The Plotter will be tested over the frequency band of 10 cps to 500 cps.

2. Both units of the plotter (display head and memory converter) are to be tested in their intended mounted configurations, i.e., display head hard mounted, memory converter shock mounted.

3. The Plotter is to be operating during testing.

4. The acceleration levels that Loral expects to test the units to should be stated, but with the provision that testing to the stated levels will be waived by GEOS if it is found that such testing levels may cause catastrophic damage. The intent is not to damage the plotter during test.

The following vibrations levels are typical of the levels that some of our equipment have been tested to, and should be included in the quote request as a guide for Loral's consideration:

5-10 cps	double amplitude .08"
10-15 cps	± .42 g's
15-30 cps	± 1 g's
30-70 cps	± 3 g's
70-500 cps	± 5 g's

NOTE

Legal considerations, scheduled problems, and cost, all influenced the final decision not to test.

3.3.6.1.12 Map Coder. An item of design nature that was also considered was a Map Coder. After much discussion throughout the program and delay caused by more pressing problems, GEOS Human Factors was requested to prepare a specification and request a quote from Loral on a Map Coding device. The following was submitted for Loral's consideration:

MECHANICAL MAP CODER SPECIFICATION

Description and Operation: North-south and east-west orientation, track-up orientation and map scale information are to be marked on four slide rule type index strips which are to be mounted in a base plate. The binary conversion for each numerical or word input will also appear on the slides. The slides and base plate are to be mounted beneath a cover plate containing windows so arranged that when a proper map input is selected by means of adjusting the slides, the proper binary translation can be read. The device is to be so constructed that the map board is held in place by locating pins or bars in such a manner that the binary code appears adjacent to the coding holes on the map board, thereby indicating which holes are to be filled and which holes are to remain unfilled. The map coding device is to be nonelectrical, have four moving parts and have a work surface protected by a Teflon (or Teflon-type) coating to prevent any surface accumulation of hole filling material. The slides shall be constructed in such a manner that the possibility of accidentally moving or resetting of the slides is minimized.

Material and Characteristics: It is recommended that either high-impact plastic, lightweight metal or a combination of both be used to construct the map coder. The use of organic materials, suchas wood, is not recommended and should be avoided. Material shall not support fungus, shall be minimally hydroscopic, shall have high impact resistance and shall be light weight.

3

Size, Weight and Finish: Overall size should not exceed 15" x 9-1/2" x 4". Weight to be commensurate with materials specified. Recommended finish is flatblack; however, finish may be dictated by choice of material.

Package Design: The coding device is to be equipped with a cover and carrying handle. A compartment for hole filler material (tube of Plastic Wood) is desirable, but not a requirement if it becomes a detriment to the overall design.

NOTE: The following is the decision made concerning the map coder:

The two map coding devices required for the AMPD-224 program will be built in-house. The decision not to buy from Loral was based primarily upon the fact that the Loral configuration was not consistent with the GE specification, and was judged to be overly complex in design and operation.

Figure 3-18 shows the finished Map Coder.

The specification and procurement of pens for the plotter are discussed in para 3.3.6.2 of this report, as well as discussions concerning map boards.

3.3.6.2 Human Factors Considerations. The primary areas of human factors concern were general characteristics of the plotter display, map boards and map coding devices, map holder, pens and ink, and environmental effects. A design study by Human Factors made during the early stages of the program is covered in para 5.2 of this report.

3.3.6.2.1 Slew Speed/Maps. A telephone call on January 19, 1967 resulted in the following understandings:

1. Slew Speed-Slow

   The slew speed-slow was to be reduced from 0.7 inch/second to 0.17 inch/second. Slew speed-fast to remain 1.4 inches/second.

2. Map Storage/Selection Technique

   Loral will propose two techniques for storing and selecting map cards:

   a. Manual—Index number to be read on plotter and manually dialed into map storage magazine which will (by lighted indicator) designate correct adjacent map.

   b. Automatic—Index number would be electronically fed from plotter to map storage magazine which would (by lighted indicator) automatically designate correct adjacent map.

The map storage magazine should incorporate a safety device to minimize the possibility of a map being inadvertently filed in an incorrect storage slot.

GEOS Human Factors, being in accord with the above approaches to the map storage problem, reserved further effort in this area until the Loral proposal was reviewed.

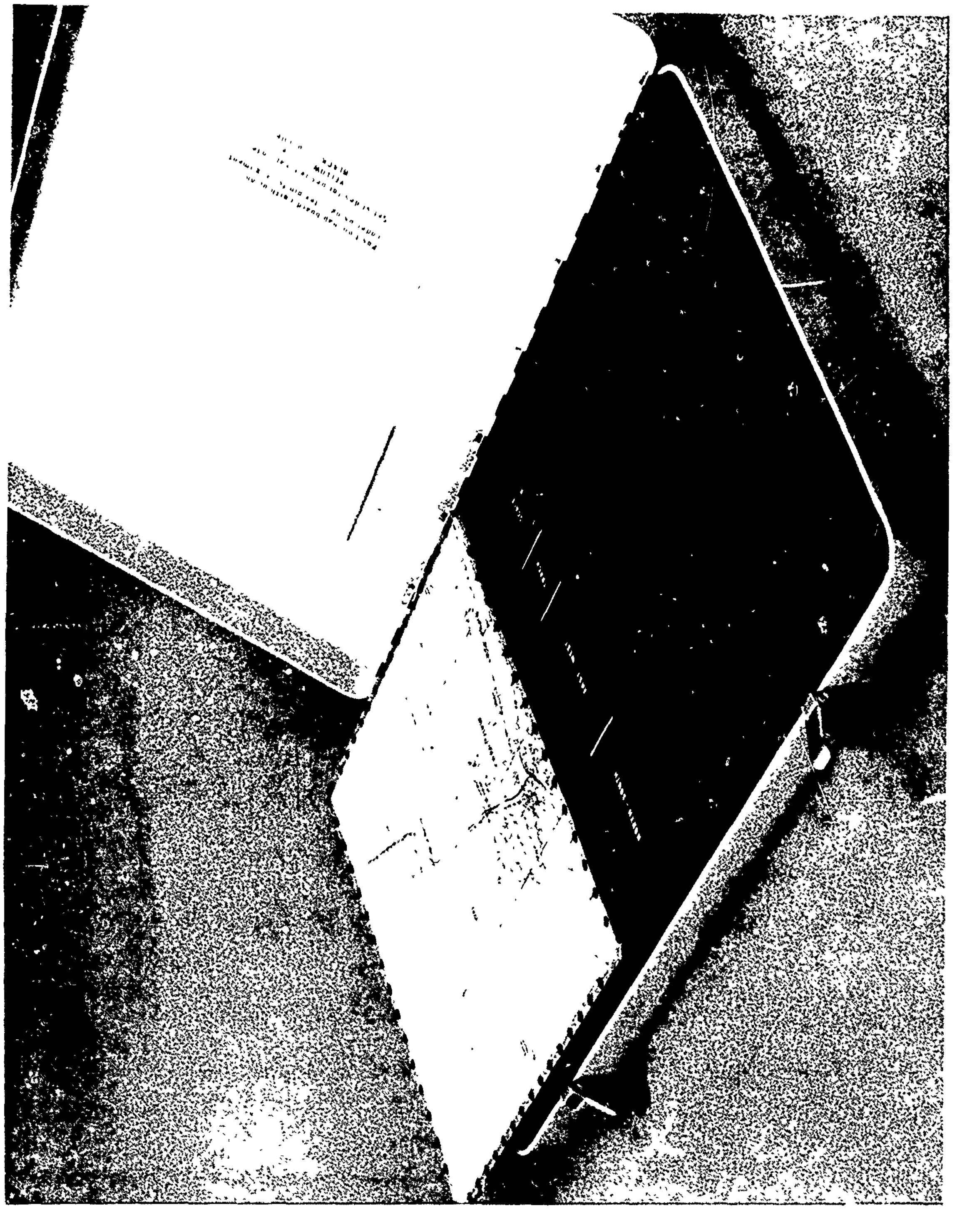


Figure 3-18. Map Coder.

3. Map Board Code

GEOS, to eliminate problems inherent with coding map boards in the field (for example, filling holes with plugs), investigated the feasibility of providing low cost, precoded sets of map boards to be used on a once-only basis.

Loral was to provide a revised map board drawing showing corrected tolerances and dimensions for index holes.

3.3.6.2.2 Quote Modification. These comments related to Loral's original product specification PS322 dated January 1967. Further perusal of PS322 and discussions resulted in the following request for quote modifying PS322:

A. Three (3) Tactical Navigation Display Systems Model TND-4 (Loral P/N 142070-000) per Loral Product Specification 322 Rev A (January 1967) with the following exception and/or modifications.

Pg. 1, para 1.2—Change slew speed-slow from 0.7 inch per second ±30% to 0.17 inch per second ±30%.

Pg. 3, para 1.4—Change from "When the cover is opened, the bug will be raised to its no-trace position" to "When the cover is opened, the bug will be raised to its no-trace position and move to the top boarder".

Pg. 3, para 1.5—Delete paragraph titled "Reset Indicator". A reset indicator is not required on the plotter control panel. A description and explanation of the reset function, however, should appear in section 2 ("Functions and Performance") of the specification.

Pg. 6, para 2.5—Change from "Specular reflections from the plotter cover must be minimized" to "Specular reflections from the plotter cover will be minimized by the use of ..... (explanation of technique)..... ".

Pg. 8, para 2.8—Add following pen qualifications as design goals:

a. pen ink capacity—300 inches

b. pen temperature operating range—0°C to 50°C.

c. pen installation and change shall require no tools.

Pg. 9, following para 2.16 (new para No. 2.17)—Require definition of chassis material, finish, color, etc.

From "Proposed Modifications to Tactical Navigation Display System Model TND-4" which accompanied Loral PS322 Rev. A, the following options were to be included:

a. option 2—extended range

b. option 3—map overlap

c. option 4—no mark command

B. Three (3) manual type map storage devices incorporating the following characteristics:

1. Desired map index number shall be a manual (operator input to the storage device).
2. Ability to handle any combination of different map scales (scalar mix capability).
3. Two piece assembly:
   a. electronics package with controls
   b. map magazine with quick disconnect from electronics package.
4. Indicator light to show requested map.
5. Pop-up device to raise requested map.
6. Indicator light to show magazine slot from which map has been withdrawn (light will automatically go out when map is returned).
7. Ability to indicate (upon operator request) a map of a different scale than that which is in the plotter (provided that another scale map of the area under the bug is available).
8. Locking device to hold maps firmly in magazine during flight.
9. Capacity—21 map boards.

C. Three (3) automatic map storage devices incorporating the following characteristics:

1. Desired map index number shall be an automatic (plotter) input to the storage device.
2. Ability to handle any combination of different map scales (scalar mix capacity).
3. Two piece assembly:
   a. electronics package with controls
   b. map magazine with quick disconnect from electronics package
4. Indicator light to show requested map
5. Pop-up device to raise requested map.
6. Indicator light to show magazine slot from which map has been withdrawn (light will automatically go out when map is returned).
7. Ability to indicate (upon operator request) a map of a different scale than that which is in the plotter (provided that another scale map of the area under the bug is available).
8. Ability to indicate (upon operator request) any desired map in the magazine.
9. Locking device to hold maps firmly in magazine during flight.

10. Capacity—21 map boards.

NOTE: Additional magazines for items B and C above should be quoted on a per each basis.

D. Three (3) sets of map boards (21 boards/set). Map boards are to be used on both sides (north up position) and will be coded one edge only. Border of obverse to be painted blue, border of reverse to be painted red. All map boards will be interchangeable between sets.

E. Two (2) map coding devices that will, upon operator request, show by lighted indicator the proper map board code for the requested map index number.

F. Three (3) sets of operating and maintenance manuals for plotter as specified in Item A. If commercial manuals are supplied, they will be amended to include all modifications incorporated in the plotter. A description of the manual should accompany the quote.

G. Three (3) sets of operating and maintenance manuals for manual type map storage device as described in item B or automatic map storage device as described in item C, whichever shall be selected for use.

H. Three (3) operating and maintenance manuals (including parts list with Loral P/N and item cost) for map coding device described in item B.

I. Field engineering services should be defined in whatever manner Loral normally provides such service (probably per diem) and quoted.

J. Documentation other than that provided in items A, F, G, and H which should be quoted is as follows—three (3) each:

1. All normally replaceable parts and components (pens, special lamps, map overlay material, etc.) shall be listed. (List to include Loral P/N or commercial name and name of manufacturer, catalog No. and cost.)

2. Complete spare parts list including Loral P/N and item cost for Model TND-4 plotter as specified in item A.

3. Complete spare parts list including Loral P/N and item cost for manual type map storage device as described in item B or automatic map storage device as described in item C, whichever shall be selected for use.

All items should be quoted by item letter (i.e.; item A, item B, item C, etc., should be quoted individually as well as in a package). Any unusually high cost item should be further broken out and explained (i.e. if item A, for example, represented a particularly costly modification it should be so noted). Product specifications are requested for items A, B, C, D, and E. The quotation submitted must include provision for the supply of outline and installation drawings and interconnecting diagrams of sufficient detail to allow preparation of specification control drawings.

3.3.6.2.3 Facility Survey. On 16 Mar 67 a GEOS Human Factors representative made a facilities survey of Loral.

A shortness of time dictated that the facilities survey be conducted at a fast walk. The following areas were surveyed in sufficient depth to allow a broad evaluation of Loral's capability:

Engineering, drafting, engineering standards, pert, purchasing, and marketing offices; environmental testing, standards (metrology), calibration, and data process laboratories; machining and fabrication, assembly, prototype, and engineering model shops.

Assembly and quality control techniques and instrument recall and calibration procedures were observed and discussed. An informal audit of measuring equipment throughout the various shop and lab areas showed no instrument to be out of calibration cycle or without a control sticker. All areas (shop, lab and office) appeared to be reasonably modern, efficient and well furnished. The general impression was that of permanency. The caliber of personnel appeared high—the predominance of white shirts and ties on the assembly line, as an example, expressed a degree of professionalism found throughout the organization.

Loral is an established organization with the facilities, personnel and attitude that qualified them as a desirable vendor.

3.3.6.2.4 Coordination Meeting. A coordination meeting on April 17, 1967 concerned the following:

Loral, to quote the operation/maintenance manual, required a more specific definition of troubleshooting and repair requirements than was provided in the RFQ (SL 3087). Firm parameters for the manual were established as follows:

1. Troubleshooting and repair procedures were to be detailed only to the point of isolating a problem to one of the two TND-4 boxes (plotter head or electronics package).

2. Maintenance portion of manual was to contain detailed schematic drawings, however, in the interest of costs, production drawings were to be used and not be photo reduced. In effect, Loral was to supply as much detail as possible without an increase in manual price.

Loral Technical Publications would write the manual in whatever format GEOS Technical Publications desired, so that TND-4 documentation could be incorporated into a complete AMPD-224 documentation package with minimum modification.

The Operation/Maintenance Manual was to be written to best commercial practice, rather than to a MIL Spec. (R&DC had not requested Loral to furnish them with either an operating or maintenance manual.) (Lehrer and Nadleback expressed the thought that Loral field service on site, (on a full-time basis), might be less costly in the long run than an expensive maintenance manual. An advantage to the full time field service approach would be that other persons (GEOS or military personnel) could be trained in maintenance procedures.)

In the event that items were returned to Loral for service, turnaround time would probably be about one month average.

Item J of the RFQ requested prices for parts lists only. Item J-1 requested price list for expendable components (pens, pinlites, etc.) and item J-2 requested price list for TND-4 spare parts.

At GEOS request, Loral was to quote item J as follows:

1. J-1. Package price for all expendable components judged necessary for one year's operation of two TND-4 units.

2. J-2. Package price for all repair components judged necessary for one year's operation of two TND-4 units.

3. J-3. (New Request). Loral labor charge (repair/return basis) to maintain two (2) TND-4 units for 1 year. The labor charge to be a bench price and include trouble-shooting, repairing units, etc.

Loral was to quote the following items by telephone on 17 April (ref para 3.3.6.22):

D - 3 sets map boards
E - 2 map coding devices
F - 3 oper/maint manuals for plotter
H - 3 oper/maint manuals for map coding device
I - field engineering services

The three portions of item J (cost of expendable components, cost of repair parts, and bench labor costs) required a reliability analysis, and therefore took somewhat longer. When Loral submitted the verbal quote on 17 Apr 67, they gave GEOS a firm quote data for item J.

3.3.6.2.5 Plotter Demonstration. On 19 May 67, a Human Factors representative visited Loral for a demonstration of the TND-4 plotter. He issued the following report:

DEMONSTRATION OF TND-4

At speeds between 100 and 400 knots (ground speed), the TND-4 was put through various trace, mark, slew, and simulated offcourse mark commands. The system was put through various map scale changes and performed well with map index, readout and map change and reset indicators functioning properly. A particularly impressive characteristic of the system was its ability to store information when the wrong map is in the head, and pick up and continue the trace when the proper map is inserted.

PHASE IV STATUS

Phase IV plotters and computer units were in preassembly stages. The Phase IV plotter map frame had been modified to provide the greater rigidity required to allow the use of plastic bead type map board plugs. The units were on schedule and GEOS was to be notified immediately if there appeared to be any cause for a slippage.

TND-4 COST IMPROVEMENT PROGRAM

Loral had initiated an active system design and mechanical design value engineering program on the TND-4 in an effort to lower system price.

STATUS REPORTS

Loral will submit bi-monthly status reports outlining progress and problem areas.

GRUMMAN OV-1D

A Loral representative related that Grumman was modifying a version of the OV-1 to accommodate a tactical display. The new version, called the OV-1D, was to be a modification of either the B or C series and was to be flight tested in the fall of 1968. He presented drawings of Loral's proposal to Grumman for mounting the TND-4 above the console center board.

Subsequent to the 17 May Loral coordination meeting, Grumman was contacted regarding the plotter mounting scheme and was to send 3 proposed layouts for review.

The Human Factors people were concerned about the method and material that Loral had recommended for mounting maps on the map boards. Some of the prepaired boards supplied to R&DC had proved to be unsatisfactory. Although Loral had reported that they had subsequently devised better methods of preparation.

3.3.6.2.6 Pens. On 22 Nov 67, a Human Factors representative visited Loral. The purpose of the meeting was to obtain information regarding pens, map preparation, map coding, and plotter operating temperature.

Because Mylar film does not have a capillary effect upon ink it is necessary to flow ink from a pen to the map surface. A felt tip pen does not flow, but rather depends upon the drawing or capillary effect of the surface being marked.

The pen-to-map pressure cannot exceed 20 gms (400 psi) without introducing servo drive motor problems. Extensive testing at Loral had shown 20 gms to be an inadequate pressure to write with a felt tip pen. The inverse is true of the Leroy pen; the lighter the pen to paper pressure, the greater the flow of ink. Because the density of the ink is critical to proper marking on mylar, it had been determined by trial at Loral that India ink gives best results (Higgens American India Ink—waterproof black).

Estabrook favored use of the Leroy type pen over the felt tip type, and had told Loral it will develop the Leroy type for them if desired. Loral Purchasing had outside quotes working on pens (details unknown). R. Oddo estimated that Leroy pens bought in quantity would cost considerably less than felt tip pens, due primarily to different method of manufacturing.

It was agreed that throw-away (non-refillable) pen design must be used. Loral was to do some homework on the pen problem; however, the homework was not defined.

A Loral representative demonstrated a Leroy pen in the plotter and performance was quite satisfactory. The pen showed good line width, density and resolution. Pen wrote well with plotter in 90-degree position while being violently shaken and jarred. Line length (according to Loral) averages about 260 inches.

3.3.6.2.7 Map Preparation.

1. Technique for cutting maps. Prior to cutting, the map must be marked along appropriate grid lines, and the map index numbers written on each of the sub-divided map elements. Maps are cut with an X-acto knife, using a straight edge as a cutting guide. (Maps that have been folded or wrinkled should not be used, as the finished surface is not smooth enough for proper marking).

2. Gluing maps to map boards. Tests conducted at Loral had shown Best-Test paper cement (Union Rubber and Asbestos Co., Trenton, N.J.) to be entirely adequate. Tests at Fort Rutgers have been satisfactory at 130°F. The following technique should be observed:

   Thin cement (using commercial thinner) until it is very light, being careful to remove any lumps from the solution. Paint both the map board and the back of the map with thinned cement, and apply map to map board using the hole or index side (south) of the board as a register point; then wipe excess cement from margin of map board.

The trick to proper map mounting is to use a properly thinned adhesive. If the adhesive is not thinned results will not be satisfactory. It was noted that R&DC used some alternate method to that which was recommended by Loral and obtained poor results.

3. Material and method for applying map overlay. Tests conducted at Loral had shown Scotch brand Magic Transparent Tape No. 810 in 10-inch width to be an entirely adequate overlay material if applied as follows:

   Apply tape over entire map and map board (avoid a wrinkled surface). The tape must be carefully sealed around the edge of the map using a fingernail or pencil. Trim access overlay material off map board, using X-acto knife and straight edge. If the overlay material is not carefully sealed about the perimeter of the map, moisture may cause the map to bubble.

3.3.6.2.8 Map Coding

1. Map coding device. Request definition of map coding device quoted by Loral 18 Apr 67. Loral will supply, by 1 Dec 67, "sufficient information to allow G.E. to have complete understanding of what Loral intended or intends to supply". Detailed procedures regarding coding, re-coding, etc. will be furnished in the form of a procedures manual when G.E. desired to purchase same.

2. Material for plugging map board holes. Preliminary tests by Loral indicated that Plastic Wood dispensed from a tube is both fast and effective. Plastic Wood can be punched or drilled out should it be necessary to re-code boards. The use of Plastic Wood may require the incorporation of Teflon as a means of keeping the work surface of the coding device clean. Loral is in the process of investigating alternate methods of plugging map board holes.

3. High Temperature Plotter Operation (above 50 deg C).

   TND-4 is designed to a maximum operating temperature of 50 deg C (per specification). Reaction of plotter to operating temperatures above 50 deg C unknown.

3.3.6.2.9 Map Coder. Upon reviewing the 18 Apr 67 quotation and item description requested from Loral, the following questions were evident:

1. Weight of unit
2. Finish
3. Bulb number and rating
4. Bulbs available in field
5. Battery life
6. Use of external jacks so that a 12 volt auto (jeep) battery could be used

In addition to item 6, (recommended by Human Factors), the following Human Factors modifications seemed advisable:

7. North-South and East-West select switches, numbered 01 through 09 rather than 1 through 9, to correspond with actual map code numbers.

8. Unit provided with a compartment (or drawer) for spare bulbs, spare batteries and hole filling material.

9. Unit provided with protective cover or case with carrying handle.

10. Indicator lights indexed on panel to preclude light bleeding from lit hole to adjacent hole, thereby confusing operator (every other hole codes opposite side of map board).

On 5 Dec 67, after reviewing the above points with GEOS Purchasing, they were reviewed with Loral. It was hoped that the necessity of a requote could be avoided, as many of the items appeared to be oversights. A Loral representative promised answers not later than 6 Dec 67.

On 7 Dec 67, a Loral representative discussed at length 12-volt military batteries (how confusing they were), the essence being, that although he had spent eight hours investigating, he had no answers, and had been told to request a requote. The information he did supply is as follows (by preceding item number):

1. Weight—approximately 7 lbs.

2. Finish—same as TND-4.

3. Unknown.

4. Unknown.

5. Unknown (later modified to "long enough").

6. Confusing problem—many different aspects to be investigated.

7. No problem—oversight, no additional cost indicated.

8. Agreed good idea but additional cost seemed probable.

9. Agreed good idea but additional cost.

10. No problem—no additional cost indicated.

On 1 Mar 68 the decision was that the map coding device as quoted by Loral was not acceptable design, nor was their price considered to be reasonable. Attached was a sketch of Reliability Engineering's concept of the device as approved by Program Management. The total cost for two devices, when designed and fabricated through Reliability Engineering was broken down as follows:

1.	Engineering hours	(502)	42
2.	Technician hours	(531)	8
3.	Technician hours	(532)	24
4.	Manufacturing Job Shop (Labor and Materials)		$ 720

Delivery on the two map coding devices was estimated to be during fiscal week 14. (Boards to be used during field test in Florida during March were hand-coded by Human Factors people in time for the test program). Figure 3-18 shows the finished map coder.

3.3.6.2.10 Map Preparation, Pens, and Ink. A meeting was held 13 Feb 68 (requested by Loral) for the purpose of comparing notes on map preparation and observing environmental tests of a new (MMM) polyester map overlay material.

Results of the Loral investigation of map curling problem were:

1. Best Test rubber cement must not, according to the manufacturer (Union Rubber and Asbestos Co.), be thinned to less than a 1:1 ratio. This contradicted the original Loral formula which called for a highly diluted cement (1 part rubber cement to 3 parts thinner).

2. Scotch brand Magic Transparent Tape No. 810 (which Loral had recommended as map overlay material) is, according to MMM Company, actually cellulose acetate (cellophane) and is very unstable. The 3M Company supplied Loral with a 4-inch roll of polyester adhesive film which they recommended as suitable for the environmental requirements of the system.

3. Map preparation technique was revised as follows:

   a. Map is measured, marked with index number, and cut.

   b. Rubber cement (50 percent solution) is applied to map board and map is applied directly over wet rubber cement. Rubber cement is applied to map board only, and is not allowed to dry before the map is placed on the board.

   c. Using a wooden roller, the map is firmly pressed to the board until no surplus cement is visible at the edges of the map.

   d. Polyester overlay film is applied to map, rolled to remove any air bubbles, and trimmed to size.

4. Environmental test procedures and results:

   Four boards were prepared in the following manner:

   a. Two boards covered with polyester overlay film (4 sides)

   b. One board covered with cellulose acetate overlay film (1 side)

   c. One board coated with spray-on type varnish (Humi Seal No. 1A27 Columbia Technical Corp (2 sides).

All boards were placed in a temperature/pressure chamber and cycled 70 deg F to 140 deg F and 0 to 30,000 ft altitude (cycle time 10 minutes). The boards were removed from the temperature/pressure chamber, inspected, and placed in a temperature/humidity chamber set at 140 deg F and 95 percent relative humidity (test time 25 minutes).

3.3.6.2.11 Test results and conclusion:

Two boards covered with polyester film showed no effect from tests.

One board covered with cellulose acetate film was rendered useless due to excessive wrinkling.

One board coated with Humi-Seal was rendered useless due to excessive stickiness of varnish.

Although physically stable within the established environmental parameters, the polyester film because of its high gloss surface is more difficult to write on than cellulose acetate. Informal tests at Loral indicated that writing with india ink was not a problem, and that greater line length could be achieved than was previously possible on cellulose acetate. Inasmuch as these tests were not observed, they must be considered more as speculation than fact until additional in-house evaluations are made.

Loral representatives were apologetic that the map preparation problem had not been identified earlier by Loral, and expressed regret that GEOS encountered a problem that they (Loral) should have resolved. Loral was particularly anxious that GEOS was satisfied that they had made a real effort to resolve the problem.

To emphasize the problem presented by the use of pens and inks, GEOS Human Factors issued the following status report on March 5, 1968.

A primary area of concern in operator evaluation of any device is personal interface with the equipment. The map plotter and specifically the manner in which it presents data to the operator is, a criteria by which the entire system is measured. The following problems directly affect the plotter's ability to perform as a part of the AMPD-224 system.

1. INK EVAPORATION. When exposed to air (when pen is removed from capsule) the ink begins to dry about the tip of the pen. Drying does not occur when the pen is in motion on the board but does occur when the pen is not in motion either on the board and not plotting or off the board in the standby mode. The ink becomes coagulated in the barrel in the pen after 5 to 30 minutes standing, depending upon the type of ink and the degree to which it has been diluted. It is sometimes possible to cause a dried pen to begin writing again by rapidly switching the plotter from ON to STBY, a sequence which taps the pen against the map board. Because environmental testing of ink is not possible in-house, the effects of the following conditions, either singly or in combination, are unknown: temperatures above 75 deg F, humidity above or below 40 to 60 percent, and sustained very slow or sustained very fast plotter speed.

2. Ink Viscosity. As the viscosity of the ink is reduced by the addition of water and a base neutralizer, it changes its critical characteristics; it becomes freer flowing in the pen (thus less apt to dry out or coagulate as rapidly), and tends to form blots or puddles rather than a continuous line on the polyester overlay film. Because the dilute ink puddles and drys slowly there is reason to suppose that vibration may cause it to run. Dilution beyond a certain point, which varies with different inks, causes a loss of color definition. Lack of environmental test facilities, again, have precluded all but a cursory investigation of the problem.

3. Line Capacity (Length) of Pen. Pen capacity is a function of the ink (amount,type and viscosity), the surface (polyester film), operating characteristics (speed, vibration, board temperature), and environment (ambient temperature and humidity). No evaluation can be made until the proper ink is selected, and in any case the evaluation cannot be made in-house.

4. Shelf Life of Filled Pens. The pen shelf life is a key question that must be answered before a logistics plan can be developed. The number of pens to be supplied to the customer and whether the pens are to be filled in-house or on site as needed are issued that must, in part, be resolved when an ink is developed and evaluated. An improved pen filling technique is presently being sought.

5. Cleaning and Refilling Pens. Vendor source and pen cost is presently being investigated by GEOS purchasing. The decision to clean and refill pens versus using them on a throw-away basis must be made in consideration of the cost of new pens and the difficulty of cleaning used ones. Factors determining the ease of pen cleaning are: amount of solid residue left in an empty pen; feasibility of flushing pen immediately after use; availability and use of holding fixture; cleaning utensils and cleaning solvents; and the time and patience factor. Again, the ink characteristics will be a major consideration.

6. Pen Insertion and Removal. The pen insertion and removal operation is difficult at a bench and must be expected to be more difficult in a moving aircraft. Whether or not a special tool to facilitate pen insertion and removal is required will be apparent during field tests.

7. Polyester Map Overlay Film. The high-gloss polyester overlay film may introduce a reflective problem, either from sunlight or plotter wedge lights. Although the polyester film has proven stable in laboratory environmental tests, its practicality with regard to ink adhesion, reflectance, and ease of preparation will be best decided after actual use.

R&DC telephoned 1 Mar 68 to inquire about the status of map preparation. Map overlay tape, ink solutions, and pen cleaning and filling techniques were discussed and notes compared. R&DC offered the C-47 plotter for the evaluation of ink solutions or overlay techniques.

On 18 Mar 68, a meeting was convened at Loral on the need for additional pens and map boards to support the plotter during flight testing in Florida and in Viet Nam.

1. Pens. Loral was asked to provide estimated prices for quantities of 100 and 800 unfilled pens. The budgetary estimates were as follows:

   a. 100 Pens (unfilled and bulk packed) $10.00 each

   b. 800 Pens (unfilled and bulk packed) $7.25 each

At these prices, GEOS was not interested in obtaining filled pens, and considered developing a new source.

GEOS Purchasing was to issue a formal RFQ for the following:

   a. Quantities of 100 and 800 unfilled Pens.

   b. One complete set of drawings and specifications for the Pen.

   c. One set of filling and cleaning support equipment.

2. Map Boards. GEOS Human Factors indicated they would need 150 map boards with holes punched on all four sides at a diameter yet to be determined. Loral furnished a map board drawing. Human Factors was to provide a completed map board print to Purchasing, who in turn will solicit a quotation for 150 pieces.

The Florida tests of the 224 Phase IV system using map boards and pen filling supplies furnished by Human Factors gave the following results:

a. Pens used was 50 percent water solution of India ink, in one pen.

b. Filled half hour before flight, about twenty minutes before use. A lift-off, procedure has been to hit pen lift 5 or 6 times to free the stylus.

c. After use, placedpen in container; no attempt made to flush out remaining ink.

d. In preparation for next flight, flush out with water syringe, then load with ink. (Pen is loaded when excess water disappears and only ink comes out). Place pen in container.

There were no problems with pen insertion/removal, though this is hardest part. (Plotter should be off, and map in, when inserting pen in bug.) Removal spring (in bug) was operative. Never ran out of ink, or skipped without provocation. Received better results using Ruby eraser instead of water for ink removal, in some cases.

e. Map Boards

One side of one board bubbled (opposite side of 1100 map); wrinkle on white boarder. Something was needed to record plot of flight for permanent record. Used was standard FN 154 (12/45) graph paper, 240 x 380 mm divisions, scotch-taped to board). Boards were coded to arbitrary grind system, and coding was changed to standard Army system.

3.3.6.2.12 Further Pen Investigation. Human Factors representatives visited Estabrook Pen Co., of Cherry Hill, N.J., 28 Mar 68, to investigate the feasibility of a prefilled, throwaway pen, to talk plotter pen concepts, and to discuss problem areas with pen specialists.

The refillable LeRoy tape pen was examined by Estabrook's chief engineer, who expressed doubt that the pen would prove as satisfactory as a plotter pen should. He expressed concern that the pen tip would wear out, thus limiting the number of times it could be refilled. It was noted that production model pens would have brass tips instead of stainless steel tips that the prototype pens had.

Following a discussion of pen life requirements (100 inches/minute), writing surface (polyester film), and plotter characteristics (speed, 50 gms pressure) the Esterbrook representative said he throught Esterbrook could furnish a prefilled, throwaway ball point pen that would meet requirements, to be supplied on a no charge basis, and available in 2 to 3 weeks.

To facilitate selection of the proper ink, a polyester-covered map board was left with Esterbrook. Nothing relative to plotter use, configuration, etc., was discussed.

At a meeting 7 Jul 68 with Loral, an aluminum map board, prepared by Human Factors, was discussed. Items covered during this meeting were as follows:

1. With some caution, Loral endorsed the aluminum map board.

2. Delivered repair parts, plus repairable Memory Converter boards and cover maintenance requirements, for six months RVN operation.

3. Plotter manual draft: Available 15 August, with delivery of final copy 20 September.

4. Test Set delivery: Imminent.

5. Pen deliveries: Scheduled (50) on 6 September; (50) on 4 October.

Loral warned about flatness and deburring of aluminum boards (item 1). Freedom of board movement, side-to-side (East-West direction) in map frame was discussed (Loral said this was normal provided the board recenters itself). The aluminum board tried on 2 July did not recenter according to Human Factors (this was to be checked). Stack-up of materials and tolerances (aluminum board is 1/8" thick) with map overlay material running to board edge might exceed space in map frame channel. (Board thickness could be reduced to compensate for this.)

Six months of RVN operation (item 2) was defined as being sixty hours per unit per month for each of the two operating plotters, with a third (spare) plotter available for interim use during troubleshooting. For these criteria, Loral indicated that delivered repair parts, plus Memory Converter boards they were quoting, should be sufficient for maintenance.

Loral required certain of the repair parts delivered to GEOS to be kept at Loral for board repairs (boards are the only factory repairable components); Loral considers repair parts delivered outside of "fair wear and tear" warranty provisions of plotter purchase order. They indicated their quote for repairable boards would be $ 22K, of which $ 3.6K was for a factory board tester.

Loral reported that the manual (item 3) would be available in draft form 15 Aug 68 with the final copy due 20 Sep 68. With the exception of factory repairable boards, the manual was written to make use of delived reports in the field. (Should major plotter head repairs be required, the unit would have to be returned to the factory). (Note: Loral recommended overhaul of the plotter head by factory instrument mechanics before shipment to RVN.) They also recommended training of GEOS people with the test set and manual, and indicated that the training effort would require about two weeks full time.

Test Set (item 4) delivery was imminent. Loral wanted access to the spare plotter at Pittsfield for operational checkout; GEOS indicated that the plotter would be kept here for that purpose. Loral's pen schedule was 50 each by 6 Sep 68 and 4 Oct 68. This was not in keeping with their quoted schedule (they indicated delivery to start in sixty (60) days and their purchase order was dated 21 June). Loral attempted to better.

Loral indicated two pens (item 5) delivered on expedited basis for C-47 use had to be handled separately. They were made in their model shop at substantially higher unit cost then quoted.

Finally, Human Factors was asked to prepare a procedure for preparing map boards and pen handling/maintenance which could be incorporated in the AMPD-224 manual. (See AMPD-224 manual for details concerning these procedures).

3.3.6.3 Problem Areas. The following contains discussions of problems which were not directly related to Design or Human Factors areas.

3.3.6.3.1 Meeting 29 Jun 67—Plotter. Several GEOS representatives visited Loral 29 Jun 67 to discuss a number of items concerning interfacing with the plotter and delivery requirements.

The plotter-to-navigator and plotter-to-Sperry computer interfaces were not completely resolved. Some interface problems needed more study before a definite solution could be implemented.

Loral had already anticipated and corrected a problem concerning the present position slew lines by adding a relay and revising some relay switching. A drawing was issued to show these changes.

The problem of the 1/100 km data lines was still unresolved. Loral was studying the inclusion of differential amplifiers, in their equipment, to provide complete isolation to the navigator. They were to contact GEOS later on available differential amplifiers (this problem is covered in para 2.2.1 of this report).

Loral also indicated that there might be a problem with line loss in their reference lines to the Sperry computer, and considered using a trimmer to offset the loss. (This problem wasn't pursued further.)

Delivery had been promised for the end of July before the interface problems were brought up. No mention of delivery date was made after that.

The plotter head was still being worked on; mechanical changes were being made to incorporate features added to the Phase II unit. There was a mechanical problem with the stepper motor reported to be solved. The motor vendor was there the same day to test the revised motor.

Pens for the plotter were still a major problem; however, GEOS was to be supplied with several reusable pens. The combination of a Paper-Mate nib (felt tip) and Hewlett-Packard recording ink worked best. Loral still needed time to consider the tip-ink problem, especially vendor interest and delivery.

Some contract provisions were discussed and quotes were reviewed. GEOS was to receive reproducible interconnecting diagrams as called for by the contract; also, a complete set of schematics, but on a proprietary basis. If GEOS were to buy their operation manual, the schematics were to be included without the restriction. Field service, the operation manual, map coding device and manual, mapboards, and the quotes on these items were discussed briefly.

The map handling case (magazine) wasn't defined enough for a quote, definition was needed on number of maps and the scale. Also, there had been no request for a quote for pen tips or necessary supplies and spare parts.

GEOS was to have installation drawings by 7 July.

Final test was expected to be the last week of July. A GEOS representative was to be at Loral for the final test and be familiarized with the operation of the system, and testing and maintenance requirements.

3.3.6.3.2 Meeting 26 Aug 67—Plotter Motor. On August 26, 1967 another meeting was held at Loral.

A Loral representative gave a brief review for the GEOS purchasing representative, and discussed their problems with the plotter. The special stepper motors had degraded with use from overheating; they also had a tendency to mis-step, slow down, or to oscillate. Loral then had two motors installed in place of the previous one, and operation seemed to be normal (the plotter head was exercised for GEOS at the meeting). The head was not completed, but needed only wiring clean-up necessitated by the position of the added motor.

Though Loral was having trouble with their core memory (the memory was lost whenever the plotter was turned off), it was reported 25 Aug 67 that the problem had been checked, and was operating properly.

The second plotter system was scheduled for delivery 18 September, which was felt to be optomistic by Loral.

The isolation problem was discussed. GEOS was to submit an RFQ to Loral for inclusion in the plotter system of the necessary circuitry. The circuit was to be added to the first unit after receipt by GEOS of the unit but it would be included in the other units when delivered.

It was expected that the first plotter would be delivered by Loral on 29 Aug 67.

When the first plotter (XN-2) was delivered (31 August), its interface with the navigator was checked and a number of marginal areas were noted; first, the plotter would not always go to the south when being driven by the navigator. A defective transistor was found in the navigator interface portion (repaired at GEOS on 1 September). Also, a stray piece of wire in the display head shorted out a motor drive transistor, and a pinched wire was found. The plotter was exercised until 13 September, when the display head became inoperative. The plotter was then returned to Loral for repairs.

The failure was caused by a defective transistor in the motor drive circuits of the display head. Loral indicated there may be some other defect; another transistor had failed previously in the same area when a wire was shorted in the bottom of the memory converter. Some marginal areas were discussed; (1) The bug would move erratically when power was first turn to "STBY" in the morning. If the plotter was then turned OFF then back to STBY, operation was normal. No explanation was offered. (2) The bug had a tendency to hang up, when the cover was closed, at the upper corner. The hang-up seemed to be cured with the replaced motor drive transistor. (3) The bug would glitch when running at maximum speed toward the left. This seemed to be a mechanical problem which still had not been completely cured in this particular display head. The accuracy of the system is not affected by the glitch but it was annoying. (4) The voltage spikes detected on the d-c and signal grounds of the plotter were caused by the switching type power supply in the plotter. There was also a ground loop in this area (discussed later). The plotter was then left at Loral so that the above problems would be completely resolved and the latest modifications (especially the isolation amplifiers) could be incorporated.

Loral decided to deliver (3 October) the second plotter (XN-3). When the plotter was plugged into the GEOS system and turned on, the operation was erratic, and it would not perform most functions. The problem was finally traced to a large current (one amp) flowing in the d-c and signal ground wires. It was found that the plotter would run properly if these wires were open-circuited. A transistor in the navigator interface circuits of the plotter failed shortly after the ground problem was defined.

A Loral representative then came to GEOS, and replaced the defective transistor and attempted to eliminate the ground loop within the plotter system. He was not entirely successful at eliminating the loop, but was able to lower the current to 0.2 amp. It appears that it would be difficult to eliminate other ties between the power ground wire and the d-c and signal ground wires. The Loral representative rewired part of the power supplies regulation circuits so that most of the high current elements were tied to the power ground wire, and opened a jumper between power ground and d-c and signal ground. A number of other circuits still returned power on the d-c and signal ground wires, which began to develop a mechanical bind, so he took the head back to Loral.

The Loral representative returned to GEOS on 19 October with the repaired display head (part of XN-3). When the display head was plugged in, the fuse in the memory converter blew out. The spare fuse was then tried and was also blown out. A wire was found pinched to the chassis in the display head. There was not supposed to be a connection between the chassis and any part of their circuit, but there was a connection that appeared like a 100-ohm resistor in series with a diode (by ohmmeter check). Several of the bug motor drive transistors were found to be inoperative, and several circuit cards had inoperative components. The pinched wire was a +28-volt power wire.

The cause of the problem was then placed on the power distribution system GEOS lab. The Loral representative thought that a voltage spike of at least 90-volt amplitude and 0.1-second duration must have appeared on the 28-volt wires going into the plotter. Attempts were made to produce such a spike, but none over 10 volt 50 usec were observed. The 28-volt supply was supplying 32 volts at that time. A number of circuits in the memory converter had also been damaged.

Another display head (part XN-2) and a set of circuit cards were set up by Loral and the plotter was eventually placed back into operation. The damage was fully assessed at Loral on the defective circuit cards and on the display head. GEOS was to continue to check out the power system for any source of trouble. It should be noted that motor drive transistors had been damaged before by shorts within the plotter. Apparently, the damage in those cases was limited to single transistors, instead of the extensive damage that occurred this time.

The plotter system then at GEOS had consisted of the memory converter marked XN-3 with the display head marked XN-2. The memory converter had been operating properly, although accuracy checks had not been made, and it had not been used with Pod 1 cabling and D/A outputs. The display head still had the glitch and did not make a proper mark symbol at times. These problems seemed to be relatively minor mechanical defects, according to Loral. The display head marked XN-3 ran very smoothly until the last day at GEOS.

3.3.6.3.3 Meeting 26 Oct 67. Loral representatives attended a meeting at GEOS 26 Oct 67.

A Loral representative discussed the reduction of the plotter step size and problems associated with grounding within the plotter. A problem with electrical noise if the Off-Course target reference voltages remains at 5 volts, and the step size reduced to 1/32 inch.

There might have been a problem with sensing the map limits because of noise and the small size of the voltage steps, necessary with the present system, that correspond to 1/32 inch steps. Other changes were not considered troublesome.

Loral was concerned about the voltage spikes that the plotter was causing; Loral found that a wire had been mistakenly fastened between the plotter d-c ground and chassis, which explained why the fuses were blown by the +28-volt wire pinched to the chassis during Loral's last visit.

A Loral representative found that the voltage spikes generated by the plotter were caused by improper filtering and the long cable lengths in the GEOS system (an RFI filter for the +28-volt power wire is grounded to the chassis); therefore, the switching transients from their power supply were being returned to ground on the d-c ground wire. A filter between the +28-volt power and power ground wires was needed.

Loral also gave a presentation of the plotter system, including the controls and the display as well as the general operation of the plotter, and a technical description of the functioning of the plotter system. Loral answered several questions concerning the digital logic operations within the plotter.

As a result of a meeting on 6 November concerning the plotter system, a number of problem areas were defined, organized as follows: functional problems noted to date; pens, map boards, map preparation; quotations and modifications; aircraft mounting; functional problems for later action.

Functional problems to date were items of immediate consequence which required vendor action. These matters were to be expedited to ensure an operational plotter for system test.

Human Factors was to be concerned with pens, map boards, map preparations, and other associated matters. Delivery of the pens and map boards from Loral were expedited.

Items that required quotations and/or specification changes included map coding device; resetting switch/light to indicate an off-map target; pen-lift while going to and returning from a target; cover-open override of all other operations.

Problems that appeared in the GEOS plotter and a number of marginal areas to be discussed with Loral follow.

1. Off-Course Target (see PS322 paras 2.9 and 3.2). Where off-course target coordinates were set-up on the plotter's display lines, the plotter responded to them without a command. It also seemed to receive the same information when moving in either "X" or "Y", and also added the signals together to form a target. As a result, X = Y displacement in all cases. The plotter wouldn't return to present position unless the coordinate voltages were removed. The plotter needed Navigator pulses, or an off-course or MARK command to initiate the preceding actions.

2. Voltage Spikes

   The voltage spikes caused by the plotters power supply needed to be minimized. There did not seem to be any part of PS322 that would be referred to for this problem, which was considered serious enough that something should definitely be done to minimize the spikes. The plotter's immunity to transients should have improved, and it would be possible to identify the sources of transients which were then masked by the spikes.

   The rest of the problems were of less importance than the first two, but should still be corrected.

3. Off-Map

   Were the plotter driven off the top or bottom border of a map section, and the cover is opened, the bug will remain in the corner when the cover is reclosed. But were the bug driven off the right or left border, and the same thing done, the bug would run down the edge to the "Y" coordinate and stop. PS322 para 1.4 (as amended on 8 Mar 67) only requires the bug to stay at a border. It was thought that the action should be the same for both X and Y off-map conditions, although it was not specifically covered in PS322.

4. Slew Speed

The bug slew speed did not meet PS322 para 1.2 per modification D, which gave it as 1.4 in/sec in fast slew, and 0.17 in/sec in slow slew. The speeds were measured as 0.33 in/sec in fast slew, and 0.26 in/sec in slow slew. Also, were the bug slewed off the top or bottom border, the plotter slewed the MIN at a very rapid rate. Were the bug slewed off the other borders, the slew continued at the same slow rate. The slow slew speed was desired to be 0.35 in/sec, maximum, and the fast slew speed to be at least twice the slow speed (1.4 in/sec, or higher, was preferred).

5. Map Frame

When a map board is left out of the map frame, the bar on the map frame depresses some of the coding switches, thereby giving illegal signals to the plotter, causing it to malfunction. See PS322 para 1.3.

Operation without a map board was convenient for making some checks during setup or testing.

6. Track-Up

The plotter malfunctioned in both east-up and west-up (PS322 para 2.4). Note that Loral has been advised on a number of occasions that only north-up was to be used for our system.

7. Mechanical

The display head at GEOS continued to glitch at times, sometimes causing a defective symbol pattern.

8. Transient Sensitivity

Transients within the plotter would sometimes trigger a MARK or top-up cycle to run. Several sources in the GEOS system would cause these cycles. It was not clear whether the plotter was overly sensitive to transients, or what the other sources of transients were. It had been impossible to trace transients because they were masked by spikes caused by the plotter's power supply.

Transient sensitivity was not covered in PS322, but Loral had indicated that the plotter has a 2.0-volt threshold for noise suppression on their command inputs.

9. Vibration Environment

The acceptable vibration environment for the plotter needed more definition. Loral had indicated that all frequencies above 40 Hz should be suppressed, but had not given any indication as to the amount of suppression needed. A brochure published by Loral indicated that the plotter meets MIL-E-5422, curve IV vibration. This required verification from Loral.

3.3.6.3.4 Meeting 22 Nov 67/Technical Problems. A meeting on 22 Nov 67 was convened to discuss several technical problems associated with the Project 224 Plotter, and to agree upon the steps to be taken to resolve them. Following are listed the areas discussed along with appropriate action responsibility. (For clarity purposes, it was agreed that the converter and head which make up the Project 224 Plotter subsystem will be followed and referred to individually; i.e., H-1, 2, 3 and C-1, 2, 3, etc.).

1. Off Course Target—Loral indicated that this anomaly resulted from a failure in the S/N 3 Converter, and that the problem was not present in S/N 2.

   Action: Loral to repair S/N 3 Converter at no cost to GEOS.

2. Voltage Spikes—Loral had provided a fix in H3 and C2 which dropped the voltage spike from 3.0 volts peak to 0.3 volt.

   Action: GEOS to evaluate and advise Loral if this level was acceptable by 20 Nov 67 to permit fix-up of the remaining units.

3. Off-Map—Loral states this operation is a natural function and characteristic of the Plotter design. Project 224 Engineering concurs.

   Action: None

4. Slew Speed—Converter No. 3 had been set a 1.4 fast slew and 0.33 slow slew. Project 224 Engineering concurs that the above speeds are acceptable. However, the speeds as measured in GEOS lab are not as reported by Loral.

   Action: Loral was to make changes to C2 and C4. GEOS was to change specification accordingly.

5. Map Frame—Again Loral advised this problem was a natural characteristic of the plotter design and not a malfunction.

   Action: GEOS was to change specification.

6. Track-Up—Loral agreed this was a failure and was to be repaired.

   Action: Loral was to repair C3. C2 was to be evaluated; GEOS to advise.

7. Mechanical Glitch—This was a failure in H2 which was not present in H3 according to Loral.

   Action: Loral was to repair H2.

8. Transient Sensitivity—Loral changed the logic of C2 on the Off-Course target command and the Symbol commands in an effort to reduce transient sensitivity. GEOS to change multiplexer logic outputs to accommodate.

   Action: GEOS was to evaluate modification.

9. Vibration Environment—Loral was to contact Grumman for details of vibration environment. Loral was concerned about the writing capability, not about physical integrity of their unit.

   (Specification does not require testing to MIL-E-5400 curve IV, but this appeared to be a critical area that should have been checked.)

   Action: Loral was to check with Grumman on typical vibration of OV-1 cockpit area.

10. Vertical Mounting—Concern about pens and additional load on carriage. Pens may leak or not write properly. Carriage would require more driving torque from stepper motors which were already marginal. Loral would consider any major problems that are encountered to be a change of scope because of the understanding that it would be used tilted. Mounting position is not covered in the specifications.

    Action: Loral was to investigate vertical operation. GEOS was to change lab setup to vertical and communicate problems for future action.

11. Top-Up Precedence—Loral said that top-up should over-ride everything. Since GEOS experienced trouble in this area, the plotter must have failed.

    Action: Loral was to fix plotters.

12. Pens—The present pens were considered unacceptable. Trouble had been encountered with filling and dried ink clogging. Loral reported that they had not had success in finding a vendor for pens.

    Action: GE Human Factors was to work with a Loral human factors representative to find a solution.

13. Map Preparation—The technique for cutting and gluing map sections and overlay material needed improvement.

    Action: GE Human Factors was to investigate.

14. Map Board Coding Device—A device was needed for coding the map boards and a method for filling the indicated holes was needed. A number of schemes had been proposed, but needed more definition.

    Action: GE Human Factors was to investigate.

15. High Temperature Operation—Loral reported that the plotter was designed to operate in the expected environment, but it had not been tested at high temperature or high humidity. It was mentioned that the drive motors might degrade at temperature, but not to any significant amount.

    Action: GE Human Factors was to investigate.

16. Top-Up Sequence—The bug's going to the right corner causes some waste of time when the cover is reclosed. This could cause loss of information while changing maps.

    Action: Loral was to investigate.

17. Map Handling Equipment—Some method for storing maps was needed when the system was to go to the customer but he had not indicated a requirement for any storage device. Therefore, this item will be considered a change of scope if the customer decides that he wants it.

    Action: GEOS to follow.

18. Plotter Specification—GE was preparing a specification on the plotter, which was to be delivered to Loral for their comments in two weeks.

    Action: GEOS was to update and rewrite plotter specification.

19. Quotations Due—Quotations for including a target offmap light and 1/32-inch step size had not been received by GEOS. Loral reported that they were in the mail.

    Action: GEOS was to consider quotes when they arrived.

20. Failure—The major failure experienced by GEOS with plotter S/N 3 was considered by Loral to have been caused by a very high voltage spike (100-120 volts) for a relatively long period. GEOS had not been able to locate any fault in the 224 system that could have caused the problem.

    Action: To be considered at the next meeting.

21. Delivery of S/N 4—GEOS preferred an earlier delivery date than 18 December. Loral was being held up by the delivery of a D/A network from their vendor (Vishey).

    Action: GEOS was to contact the vendor to arrange earlier delivery of the component.

22. Return of Plotter (Convert XN-3, Display XN-2)—Loral was to repair the plotter in which the previously mentioned problems have been noted. Loral planned to return it on 28 November, which was also the date of the next integration meeting with Loral.

    Action: GEOS was to check out the plotter when received, and to try and improve the 21 December D/A network delivery date.

The next integration meeting with Loral was at GEOS on 28 Nov 67.

Purchasing contacted Vishey about delivery of the D/A network. Vishey indicated that the delivery date had been moved out to 21 December. Further efforts were to be made to improve the date.

3.3.6.3.5 Return of Plotter (Converter XN-2, Display XN-3). A Loral representative arrived in the afternoon of 15 Nov 67, and checked the GEOS plotter (Converter XN-3, Display XN-2), and noted that the deficiencies which had been discussed with Loral were still present. He took this plotter back to Loral for repairs and updating.

The returned plotter (Converter XN-2, Display XN-3) preliminary tests were satisfactory, but it was evident that some changes had been made in their logic.

The logic input of the OFF-COURSE COMMAND has been inverted such that an open circuit (or logic ONE) is normally required. This change had been discussed with Loral during the previous meeting. (27 Oct 67), when it had been agreed that inverting the logic for this input was acceptable, and that it should provide better transient supression. However, the multiplexer wiring had not been changed to the inverted configuration; the appropriate changes were then made in the multiplexer.

The Loral representative then checked the interface with the navigator and started looking for transients while the multiplexer was being rewired. It was found that the interlock relay in the navigator was causing a voltage spike of about -30 volts on the interlock wires to the plotter. This spike caused the plotter's memory to reset to zero, and also caused the plotter to mark. This problem was solved when a diode was connected across the relay coil so that the negative spike was suppressed. A transient in the compass system also caused the loss of memory and mark. This was also thought to be caused by unsuppressed relay coils. Suppression external to the compass electronic unit was attempted, but was not completely successful. Later, the problem was found to be associated with both the lack of suppression diodes on a number of relays and a transient being transmitted on the 400-Hz power wires. A definite solution for making the plotter insensitive to transients on the 400-Hz power had not been found at that time.

An attempt was then made to interface the plotter with the Pod 1 equipment. However, the D/A outputs were found to be defective, and excessive noise was being generated on the plotter analog lines by the synchro-to-digital converter. As a result, the plotter was unable to respond properly to the signals and testing had to be stopped. The problems were then solved and the plotter's response to the analog OFF COURSE TARGET Coordinates was completely satisfactory. The plotter's response to the OFF COURSE COMMAND and the symbol commands also was satisfactory.

3.3.6.3.5.1 Plotter Problems (Converter XN-2, Display XN-3.) Two deficiencies were found in the present plotter system. They were as follows (refer to "Electrical/Mechanical Problem Areas Associated with Loral Plotter—TND-4"):

3.3.6.3.5.2 Slew Speed—The bug slew speeds still did not meet the reported or specified slew speeds. The speeds were measured at 0.274 in/sec in fast slew, and at 0.067 in/sec in slow slew. Loral had reported that the speeds were 1.4 in/sec in fast slew, and 0.33 in/sec for slow slew.

The second problem is referred to PS322 Rev A, para 2.12. The plotter lost memory every time the plotter was turned OFF. The specification requires that present position will be maintained during power OFF.

3.3.6.3.6 Meeting 2 Dec 67/Technical Problems. A meeting was convened to discuss technical problems associated with the Project 224 Phase IV plotter and to agree on the steps to be taken to resolve them. The areas discussed are listed as follows with the appropriate action responsibility. Refer to the "GEOS—Loral Plotter Coordination Meeting held at GEOS 16 Nov 67" memorandum for more definition of the problem areas. The comments refer to C3 and H2 unless otherwise stated.

1. Off Course Target—Loral reported that two relay driver transistors in C3 were defective. These transistors were on a card that had not been changed at the time of the major failure in this unit. Loral, therefore, assumed the transistors were blown at that time and not detected until later.

   Action: None

2. Voltage Spikes—GEOS concurred this was no longer a problem with the modified plotters. The spike amplitudes from both plotters were 200 to 300 millivolts. Some maximum voltage spike should be included in the plotter specification.

   Action: GEOS and Loral were to negotiate details for including maximum spike voltage in specification.

3. Off Map—No Action

4. Slew Speed—A Loral representative stated that a module must have failed in C2 causing the fast slew speed to be .33 inch/sec. He also admitted that a mistake had been made by Loral when analyzing slewing speeds, such that the 1.4 inch/sec slewing speed is no longer possible. This came about by a change in the maximum motor driving rate which GEOS allowed Loral to change so that Loral could meet (PS322 Rev A, para 2.6) with 10-second maximum allowed for an off-course target. The maximum slewing rate is now 0.6 inch/sec, now in both plotters as fast slew. The slow slew speed is .07 inch/sec.

   Action: GE was to evaluate slew speeds. Loral was to advise as to numbers to be included in plotter specification.

5. Map Frame—No action

6. Track Up—Loral reported that there were defective switches in the slew control.

   Action: None

7. Mechanical Glitch—There was no evidence of the mechanical glitch in either of the display heads that GEOS then had.

   Action: None

8. Transient Sensitivity—Loral had incorporated the logic change in both plotters. GEOS was to consider hiring a Loral representative to investigate for transients in system at GEOS.

   Action: GEOS was to continue investigations.

9. Vibration Environment—Loral contacted Grumman about the typical vibration of an OV-1. Grumman indicated that 1.3 g's at 18 to 25 Hz and 70 to 75 Hz was typical. Therefore, Loral had recommended hard mounting the display head. GEOS wanted a search vibration test made on both the display head and the memory converter. GEOS preferred to have Loral do the test under contract. Loral would require a GEOS accepted plotter for the test.

   Action: Was to be discussed further.

10. Vertical Mounting—Loral reported no problem with vertical mounting of the display head. A GEOS Human Factors representative witnessed some tests at Loral, and reported that vertical operation was satisfactory.

    Action: GEOS was to test further.

11. Top-Up Precedence—Loral said that it was possible for noise on the top-up line to trigger their logic. This would cause the bug to move to the present position, or attempt to, if obstructed such as when the map frame is in its released position. A logic gate and/or a logic inversion might be needed to solve this problem.

    Action: Loral was to investigate.

12. Pens—Loral said that the pens should operate properly from 0 to 50 deg C. A GEOS Human Factors representative reported a test at Loral in which the pen wrote properly while the display head was being severly jarred, and that the Leroy type pen Loral had was satisfactory. Disposable pens would be required for customer use. GEOS would like to specify 200-inch writing by the pens; Loral wants time to evaluate before the 200-inch requirement is written into the specification.

Loral is still having trouble getting pen quotes from vendors. GEOS purchasing was to go to vendor for quotes on receipt of prints of pen drawings from Loral.

Action: Loral was to send prints of pens and the fourth pen.

13. Map Preparation—Loral reported that R&DC had not used the recommended procedure for fastening maps to the boards. Loral has had maps on map boards at Ft. Rucker for six months without any temperature or humidity problems. Human Factors concurred that Loral's method seems to be adequate.

Action: Human Factors was to continue investigation.

14. Map Board Coding Device—Various types of devices that could be used such as a slide calculator or fully automatic types, and materials suitable for filling the holes was discussed.

Action: Loral was to requote on the coding device they had previously designed, and to send a description of the device.

15. High Temperature Operation—Loral reports that the integrated circuit modules and memory are rated at 0 to 70 deg C. The rest of the components should be good at 0 to 50 deg C (this includes the mechanical parts). GEOS wanted to specify a definite temperature range.

Action: Item was to be considered later.

16. Top-Up Sequence—Loral indicated the plotter's logic could be wired so that the bug goes only to the top border and not to the corner. However, they had not checked if enough pins were available on a circuit board.

Action: Loral was to ensure that the wiring could be accomplished.

17. Map Handling Equipment—This was a GEOS item that no longer concerned Loral.

Action: None

18. Plotter Specification—The revised and updated plotter specification needed more revision and added descriptive material for GEOS purposes. Therefore, Loral was to receive the first draft in about two weeks for comment.

Action: GE was to revise specification.

19. Quotations Due—GEOS had received the quotes on the target off-map light and 1/32-inch step size. Loral said that the light could be installed at GEOS as a modification kit, thereby causing a minimum of interruption of system test. The form of the technical manual still had to be defined.

Action: Loral Technical Publications was to contact GEOS Technical Publications for better definition of requirements.

20. Failure—Loral had sent a quote covering the expense of damaged parts and the repair time incurred as a result of failure.

    Action: GEOS was to consider the quote.

21. Delivery of S/N 4—The component ordered from Vishay failed while in QC. This caused the delivery date to Loral of the component to slip to 21 Dec 67. Loral was to try to deliver by 31 Dec 67, if possible.

    Action: GEOS Purchasing was to continue to urge early delivery of the component.

22. Return of Plotter (C3, H2)—This plotter was returned and carefully checked. It performed all operations properly in the lab test setup and interfaced with the navigator. The Pod 1 equipment was inoperable. Therefore, that interface could not be checked in the system (this interface had been checked in the test setup, however).

    Action: None

23. Off-Course Command—An IC gate had failed in C2, causing the plotter to be unresponsive to off-course commands. The IC had been replaced, and C2 then responded properly to off course signals.

    Action: None

24. Spare Parts and Supplies—This area was not well defined at that time.

    Action: Was to be considered later.

25. Loss of Memory with Power Turn-Off—C2 lost the present position information every time the plotter was turned off. PS 322 Rev A, para 2.12 required that the plotter will retain this information.

    Action: Loral was to repair.

    (The next integration meeting was to be at Loral on 13 Dec 67.)

3.3.6.3.7 Meeting 15 Dec 67/Technical Problems. A meeting was convened to discuss technical problems associated with the Project 224 Phase IV Plotter, and to agree on the steps to be taken to resolve them. The areas discussed follow, with the appropriate action responsibility. See "GEOD Loral Coordinating Meeting held at GEOD 28 Nov. 1967" memorandum for more definition of the problem areas. The comments refer to both plotters then at GEOS, unless stated otherwise.

1. Off-Course Target—No action

2. Voltage Spikes—No action

3. Off-Map—No action

4. Slew Speed—GEOS concurred that the present slew speeds were acceptable. The slew speeds were 0.6 in/sec in fast, and 0.07 in/sec, in slow slewing.

   Action: The plotter specification was to be revised to incorporate the present slew speeds.

5. Map Frame—No action

6. Track-Up—No action

7. Mechanical Glitch—No action

8. Transient Sensitivity—GEOS reported that significant progress had been made in this area. No further action on Loral's part was required at this time.

   Action: GEOS was to continue investigations.

9. Vibration Environment—Loral had received the request for quote on vibration testing. GEOS purchasing pointed out that Loral should clearly state the ownership of the unit to be tested, and who pays for repairs and parts, as part of the quote.

   Loral planned to test to the highest levels of vibration that seemed to be reasonable as the test continued. Loral expects to go beyond the guide line levels that were to be included in the quote.

   Action: Loral was to send quote.

10. Vertical Mounting—No action

11. Top-Up Precedence—Loral reported that isolation for the top up signal line from their logic could be incorporated. Some rewiring was required and an IC module had to be added to a circuit board. Loral was to add this modification at the time the Off-Map lignt modification was made.

12. Pens—The fourth pen was received by GEOS but the pen prints were not. Loral reported that they now have a vendor quote for making pens.

    Questions: How many pens does GEOS really need? It is feasible for Loral to set up an automatic type of pen filling and packaging facility? GEOS indicated that 24 pens might be the right number at that time.

    Action: GEOS Human Factors was to be contacted.

13. Map Preparation—Human Factors had ordered materials to work with. Nothing further had been done.

    Loral questioned whether map preparation should be covered in the technical manual on the plotter. It was suggested that GEOS Human Factors might take care of this item.

    Action: GEOS Human Factors was to be contacted about the write-up on map preparation.

14. Map Board Coding Device—GEOS had received the quote and description of Loral's concept of the device, and considered the price to be higher than expected, and preferred a different approach to the device. GEOS showed several sketches of alternatives prepared by Human Factors. GEOS was planning to write a specification on the map coding device that seemed preferable. Loral would then be asked to quote for building the specified device.

    Action: GEOS was to consider further.

15. High Temperature Operation—GEOS reported that temperatures as hign as 138°F had been seen in the cockpit of OV-1s while on the ground. Loral decided that they would check the next plotter in an oven before shipping it.

    Action: Loral was to recommend the temperature to be included in the spec.

16. Top-Up Sequence—Loral could not incorporate the necessary circuitry on the existing circuit boards. Therefore, it appeared that the cost would be prohibitive to alter the sequence.

    Action: None

17. Map Handling Equipment—No action

18. Plotter Specification—The revised specification was not ready.

    Action: GEOS was to complete the specification.

    Quotations Due—GEOS Purchasing asked if Loral's adders were legitimate DCAA rates. A Loral contracts representative was not present, so no authoritative answer could be given. Loral's rates are monitored by the Navy; Loral thought that they must be legitimate.

19. Off-Map Target Light—GEOS expressed the thought that $ 6.00 was too low a price for three switches. Loral concurred and added that other parts were needed. The conclusion was that 6.00 for materials was in error. $ 6,396 for engineering for engineering labor was also questioned. Loral thought that 40 hours for drafting was included in the figure; 40 hours should not be needed for the proposed method of modifying the plotter's panel. It was concluded that Loral should requote this item.

    Action: Loral was to requote the Off-Map Target Light.

20. Failure—Technical aspects of the plotter failure were discussed at length. One conclusion was that the short circuit found in the plotter should have prevented damage. It was also concluded that an over-voltage (120v) could not explain some of the damage. GEOS pointed out that some transistors had failed in the same circuit before, and that shorts were also found at that time. It was also pointed out that the transistors could not withstand surge voltages allowed by MIL-STD-704A.

    The fact that GEOS had not been able to cause an over-voltage condition from the lab power supply was considered during the discussion.

    The final conclusion was that no definite cause of the failure could be identified.

Action: To be discussed further.

21. Delivery of S/N 4—The latest date Loral got from Vishay for delivery of the digital to analog network was 19 December. Loral was to check Vishay on the unit. Loral also needed a precision follow up potentiometer (Heli-Pot). Heli-Pot would only indicate delivery sometime in January. Loral was to try using a normal potentiometer to setup the plotter

    Loral planned for delivery on 15 January, assuming that they received the parts before then.

22. Return of Plotter (C3, H2)—No action

23. Off-Course Command—No action

24. Spare Parts and Supplies—To be considered later.

25. Loss of Memory with Power Turn-Off—Loral replaced a defective module in C2. Both plotters then worked properly on the test setup, but intermittently lost memory when connected to system at GEOS.

    Action: More study was needed to define the source of this problem.

26. Off-Course Target During Change Map—The plotters would hang up when an off-course target command was received during an off-map condition. Loral said that this is a characteristic of the plotter and that the command would have to be inhibited outside the plotter.

    A GEOS consultant pointed out that Loral should be able to inhibit the command within the plotter.

    Action: This item required further consideration.

3.3.7 Data Handling Subsystem

3.3.7.1 Data Handling Subsystem. In February 1967, effort was initiated to establish a realistic Phase IV engineering schedule.

Also, a quote was received from Kennedy on revised magnetic recorders and new readers. Purchasing was instructed to place an order per the quote. Also, manpower and material estimates were quoted for Phases IV and V to R. Gillmeister, and order information was transmitted to Purchasing on the following items by the end of February:

1. 3C module requirements

2. 3C militarized chassis

3. Astro S/D converters

4. Sperry computer

During March, spare parts requirements were also discussed and a recommended list of spares and associated costs presented by Sperry for GEOS consideration. Time and material quotes for Phase IV were submitted to Program Engineering during this period. Also, QC representatives were visiting Kennedy, Sperry, Astro-systems, and RC/95 in April, and an estimate of spare parts and Hangar Queen components required to support Phase III and IV was compiled.

In June, design specifications were issued covering Circuits Engineering effort required to design and build Phase IV amplifiers, level converters, filter, and reference power supplies. Circuits Engineering was also requested by design specification to investigate potential data handling subsystem grounding and shielding problems, and to recommend procedures to be followed when wiring pods and aircraft.

A quote was submitted covering participation in flight tests from September 15 to November 15 and local support of the Data Handling Subsystem, and a requote was submitted to the Program Engineer covering effort through May 1968, and including work statement and change in scope items.

In the hardware area for June, design effort was in progress on a full-time basis on Phase IV multiplexer logic, decimal readout, and subsystem cabling and wiring. Sketch documentation was also in progress.

Phase IV drafting requirements were reduced by a transfer of documentation responsibility to R. Kenyon's group.

Shipment had been received on the following major equipments for Phase IV by June 1967:

1. Mk 12 computers No. 1 and No. 2 and associated equipment (out of 3)

2. S/D converters No. 1 and No. 2 (out of 3)

3. Thirty multiplexer chassis No. 1 and No. 2 (out of 3), and a majority of the 3C logic modules

Still due major equipments were:

1. Kennedy recorders

2. RC/95 A/D and D/A converters

Supplementary design specifications were issued redefining Circuits Engineering effort on Phase IV.

In the softwave area, funding was approved for the generation of assembler and simulator programs for the Mk 12 computer. Engineering Computations effort on the assembler should be completed by early July. Simulator effort will follow.

In July, a revised schedule for Phase IV was drawn up and discussed with the Program and System engineers. Heavy effort required on Phase IV system assembly and test during September-October was in conflict with Phase III test support. Considerable effort was directed toward cleaning up hardware design during this period.

During August, Systems Engineering was provided with a complete set of subsystem connectors for both Phase IV systems except for the Kennedy recorder. All computer peripheral gear was loaned to Systems Engineering for pod mockup mount and cabling effort. Cables and gear were returned to Weapon Control Computer Engineering for bench test. A preliminary set of cabling drawings was delivered to Systems Engineering and cable availability requested for specific dates during Phase IV subsystem test.

In September, a special plotter test circuit was constructed and delivered to Systems Engineering, and a meeting was held to establish whether or not to provide special protection interlocks for the Mk 12 computer to prevent inadvertent loss of memory in flight.

It was decided to rely on strict operating procedures (power ON-OFF sequence) as the best protection for the present. An attempt was made to isolate and correct any potential problems in this area on a complete system basis after aircraft installation.

Progress was made in October on the Discon decimal display. Decimal display design is complete. A Discon Engineer visited GEOS for final discussion of requirements and an order was placed by Human Factors.

Subsystem No. 1 made significant progress. Lab tests were completed on subsystem No. 1, using actual Pod cabling, and the subsystem shipped to OP 8 on 23 Oct 67. Subsystem hardware had been mounted to the Pod, and was currently being checked out with actual system interfaces. Checkout was scheduled for completion by the middle of this period.

In getting DHSS No. 1 on the air at OP 8, several wiring and documentation errors had been discovered, and brought to the attention of the systems engineer.

During November, and investigation of filter requirements for 28v power source had been initiated and preliminary filter mounting requirements specified for Pod 1. System interface checkout had been in process at OP 8, a significant number of test berth wiring errors were found and corrected, and most system interfaces were checked. System operation was successful enough to allow full exercise of the plotter by the software. Bench checkout of software was completed for math models 1, 2, and 3, with source location accuracy exceeding system requirements.

In the software area, subsystem checkout procedures were being run and system test was to begin next period. Subsystem 2 bench testwas near completion at OP 2; shipment to OP 8 before 18 Dec 67 was anticipated.

An initial cut at van requirements for the Data Handling Subsystem was discussed with GSE engineer.

During December, system test was delayed by continuing hardware and system noise problems in System 1. System test was to be completed during the next period. The following attempts were made to eliminate noise p· blems:

1. Partial shielding of synchro and reference lines in aircraft cabling previously unshielded. (The resulting configuration is still not as thoroughly shielded as the Phase II system.)

2. Installing filters on the A/D converter input lines (not on Phase II.)

3. Installing filters on the S/D converter input lines (not on Phase II.)

4. Instituting a multiple ground point system in Pod 1 (Phase II utilized a single signal-chassis ground connection point).

5. Repair of various noise generating devices in the chemical and data handling subsystem.

These fixes had brought the signal noise level under control but resulted in a Phase IV hardware and cabling configuration that was significantly different from the Phase II configuration.

Component failures have increased during this period. DRO power supplies, Mk 12 computer, S/D converter and D/A converter units have failed. The latter two failed subsequent to pylon connector mismatch which caused a 28-volt short in the system during test berth rewiring operations.

On System 2, the bench test of Pod 1 gear was completed and equipment delivered to OP 8 1 week ahead of schedule (11 Dec 67). Subsequent effort on this system consisted mainly of Pod 1 wire check. Priority on this system had suffered from increased Phase II activity and Phase IV delays on System 1. Follow-up action on flight test and van requirements included specification to OP 8 of bench test equipment required and a visit to Sperry and Astrosystems concerning equipment maintenance and spare parts requirements for the coming year. Hardware problems in System 1 were eliminated to the extent of permitting an abbreviated system test (Data Handling Subsystem exceptions were the Kennedy Recorder and DISCON Decimal Display). Sufficient tests were to run to prove operability of software/hardware combination, including chemical and plotter system interfaces.

An OP 2 Mk 12 bench system was put on the air to improve debug capability over the 704 simulation program, and hardware failures stabilized during this period; no major failures occurred.

System 1 was scheduled to move to Westover Field for aircraft installation.

System 2 was put on the air in OP 8 24 Jan 68. Current debug effort concentrated on:

1. Noise elimination, computer to D/A signals

2. Removing wiring errors in Pod 1

By March 1968, major progress had been achieved on both systems. Both systems were on the air and ready for Florida test site operations beginning 11 Mar 68. All hardware and software was operating except for decimal display gear which was installed later. Systems 1 and 2 were software compatible at this time.

Noise problems in System 2 were significantly reduced by rework of level converter circuits to improve threshold level. This particular noise problem had never occurred in the other two systems, and appeared to be the result of differences in the construction of System 2 hardware/cabling.

System 1 was shipped to Westover for aircraft installation and initial flight test. Equipment was fully installed and operating in a two-week period. During April, operating procedures were written for the S/D converter test kit and the A/D—D/A converter test kit. The above kits and the multiplexer kit were checked out in the lab. Spare lamp displays were provided for test equipment design effort on a consulting basis. Significant progress was made in both DISCON decimal display and DIGITRONICS optical reader. Field activity was nil due to breakdown of maintenance van and required re-work on several aircraft equipments.

During May, the final helicopter (UH-1) checkout was completed. A functional description of the DHSS, using FBDs as a guide, was generated. Operating procedures were written for the multiplexer test kit.

In July, Florida flight tests were in progress. An emergency trip was made over the weekend of July 6 to assist in removing several problems.

Although the OV-1 left Pittsfield airport with the Data Handling Subsystem in apparent good shape (both hardware and software), several problems developed during the Florida test period.

1. Two unchecked, last-minute program modifications proved faulty in the field and caused some flight test delay until they were fixed.

2. The recorder fan was replaced as a precautionary measure. Subsequent wiring errors temporarily prevented power from reaching the recorders.

3. The Mk 12 Computer memory failed and was replaced by the C-47 CMU unit.

4. Kennedy recorder tapes did not read out properly at the University of Miami 7040 computer center. This situation improved after aircraft tapes were rewritten on a 1401 computer.

5. Evaluation of the OV-1 program was prevented by the preceding failures, and several other failures outside the data handling subsystem area.

The visit to Aberdeen was made during the week of September 30 due to investigate instability of digital data in flight and frequent loss of computer memory. Loose mechanical grounds in the Multiplexer were bypassed electrically to eliminate the first problem. The memory loss problem could not be duplicated in the field.

3.3.7.2 Tape Recorder. The history of the Kennedy magnetic tape recorder is fully documented under paragraph 2.2.2, including problems encountered with recorder design and implementation of the readout of recorder-produced tapes at commercial computer installations.

3.3.7.3 Mk 12 Computer. In March, 1967, Sperry performed acceptance test on the first Phase IV Mk 12 computer which was witnessed in part by GEOS. By April, this computer was received and the second computer was FATS tested and due for shipment from Sperry. The second Phase IV Sperry Mk 12 computer was received in June 1967.

During 1967 and 1968, the Phase IV Mk 12 computers were operated in various ground and airborne systems. Several minor circuit failures were experienced during this time, and repaired by Sperry personnel. More serious failures were experienced with the DRO power supply used with the Mk 12 computer, and these are documented elsewhere. The major Mk 12 failure during this period was the failure of one core memory stack during July 1968. This unit was repaired by Ferroxcube and put back into the spare Mk 12 computer. The failure was due to an internal short in the core memory stack and represented a difficult and time-consuming repair and retest job by Ferroxcube.

3.3.7.3.1 DRO Power Supply (Mk 12 Computer). In the first quarter of 1967, DRO memory loading requirements were established as a means of preventing bit-dropouts during computer turn-on and turn-off. Problems had been experienced with bit dropping during test. In October, 1967, DRO Power Supplies (both damaged at GEOS during OP 8 installation) were returned to Saratoga Industries for repair; they were repaired and returned by Saratoga Industries in November 1967.

By December, 1967 a noise problem was generated on the 28v lines by the DRO power supplies, and two more DRO power supplies were returned to Saratoga Industries for repair and correction of high noise levels on 28v input lines.

Early in 1968, the failure of DRO supplies to maintain acceptable regulation on the 25v output was discovered. A DRO power supply modification was installed in the DRO supply to correct this problem after Sperry personnel investigated and isolated the problem (May 1968).

3.3.7.4 Multiplexer. Both ruggedized 3C multiplexer chassis were delivered to the factory for Wire-Wrap on 2 Aug 67.

System 1 MPXR was 90-percent wired that month, and tested with peripheral gear in September, and by the end of September, was on the air and operating with S/D converter and actual Pod harness. System 2 MPXR was nearing completion of connector wiring.

By November, wiring and logic checking was complete on MPXR 2, and subsystem 2 checkout was initiated with A/D, S/D, and D/A equipment.

Data handling subsystem 1 with MPXR 1 was shipped to OP 8 on 23 Oct 67, and data handling subsystem 2 with MPXR 2 was shipped to OP 8 on 12 Dec 67.

No major MPXR problems were encountered with either system until March, when multiplexer changes were installed to allow the use of either Phase IV Kennedy recorder in System 2. The recorders at that time had different interface circuitry. Also in March, multiplexer design and maintenance documentation was essentially completed. Effort was initiated in March on the checkout of a spare multiplexer. However, spare multiplexer completion was delayed by lack of connector parts.

In May, the spare digital multiplexer assembly effort was completed, except for some wire dressing. Digital multiplexer logic prints and timing diagrams were turned over to Drafting, and in June, redrawn multiplexer prints were received from the contractor and checkout of drawings begun.

In July, wiring was completed on the spare multiplexer. Remaining effort in the MPXR area during 1968 was concentrated on occasional aircraft checkout, card replacement and minor design change.

During the aircraft test flights, the operation of the MPXR was considered to be stable and reliable.

3.3.7.5 Source Location Readout. A request for quote was placed with vendors for decimal readout equipment in September, 1967, after it was decided to include a high accuracy readout device in the Phase IV system as a supplement to the plotter.

In December, 1967, the DISCON decimal readout breadboard was received and tested in OP 2. Initial operating problems were straightened out with the vendor, and the breadboard was being interfaced with the OP 8 system. During checkout, several interface problems were encountered with the DISCON gear. The DISCON decimal display contained some logic errors and was returned to vendor (debug effort was continued at Westover).

By March, 1968, the repaired and revised DISCON decimal display gear was connected and one axis made to operate under program control. Six driver circuits failed in the course of testing with a faulty DISCON power supply. The vendor later agreed to replace this equipment. Aircraft installation was waiting on the replacement circuits.

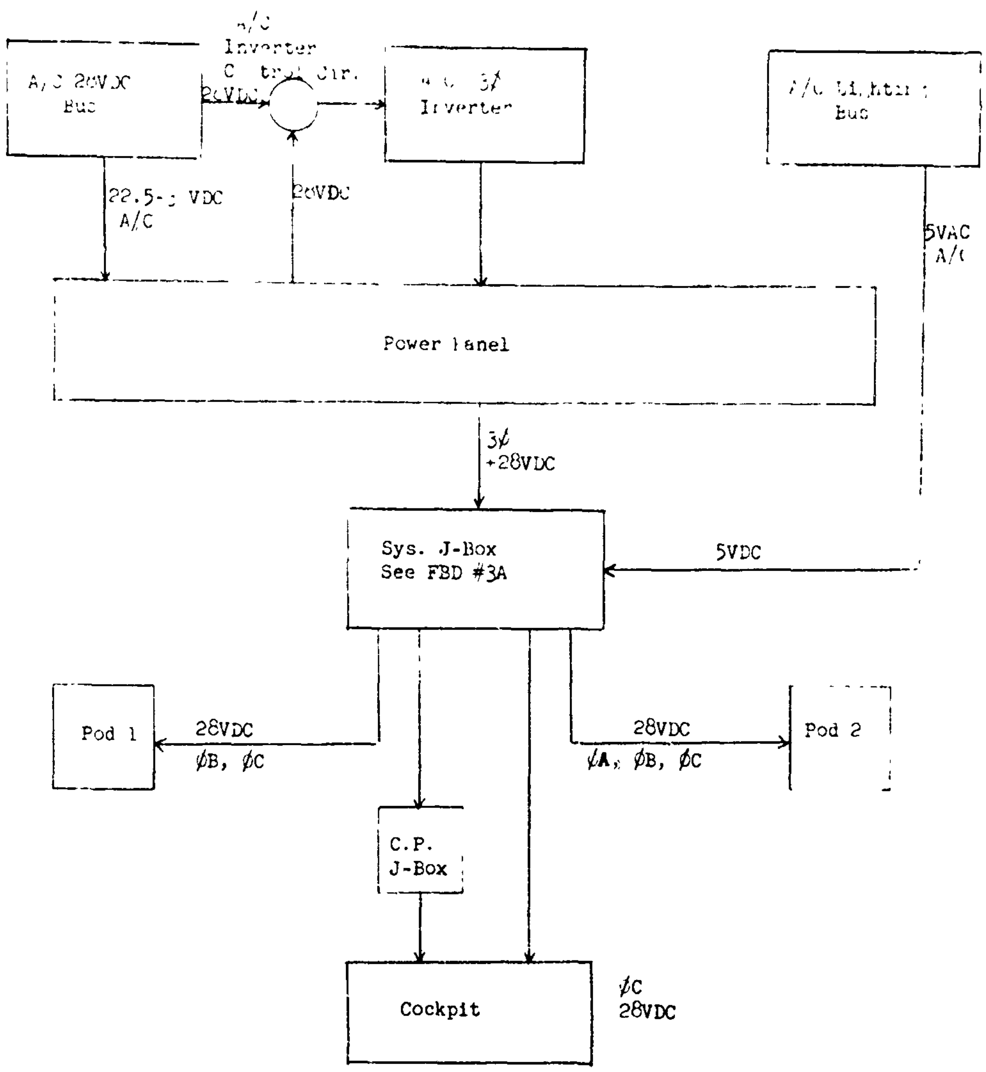


Figure 3-19. Power Distribution Block Diagram.

In April, 1968, the DISCON system was reassembled on the bench with an improved power supply, and successfully operated for extended time periods. This equipment was installed in the OV-1 and thoroughly checked out in May 1968. DISCON Corporation sent back six repaired Driver/Decoder Modules in May. By June, 1968, installation was completed on DISCON hardware in second OV-1 at Aberdeen.

3.3.8 Power Subsystem

The Power Subsystem controls the distribution of +28vdc aircraft power, 400Hz 3ϕ 115v inverter power and 5v aircraft lighting bus power throughout the AMPD-224 System. Figure 3-19 shows the power distribution block diagram; see FBD 3 for description of the power subsystem.

The characteristics of the Leland inverter are as follows:

Input Power:	26vdc - 29vdc
Output Power:	115v, 400 cycle, 3
Power Capacity:	2500va
Regulation:	115v ± 1.5vac
Adj Range:	±10vac
Configuration:	WYE

Start-up power surge requirements:

Leland 800a/0.25 second
Grumman 400a/0.25 second

The inverter is not started until the aircraft engines are running and the d-c generators are on. Control of the system inverter is obtained with a 5-amp circuit breaker (CB-10) mounted on the system power panel. Figure 3-20 shows the control circuit.

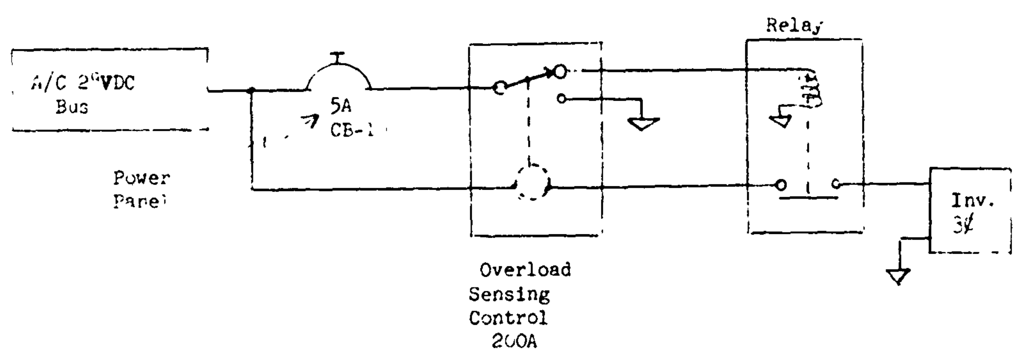


Figure 3-20. A-C Inverter Control Circuit.

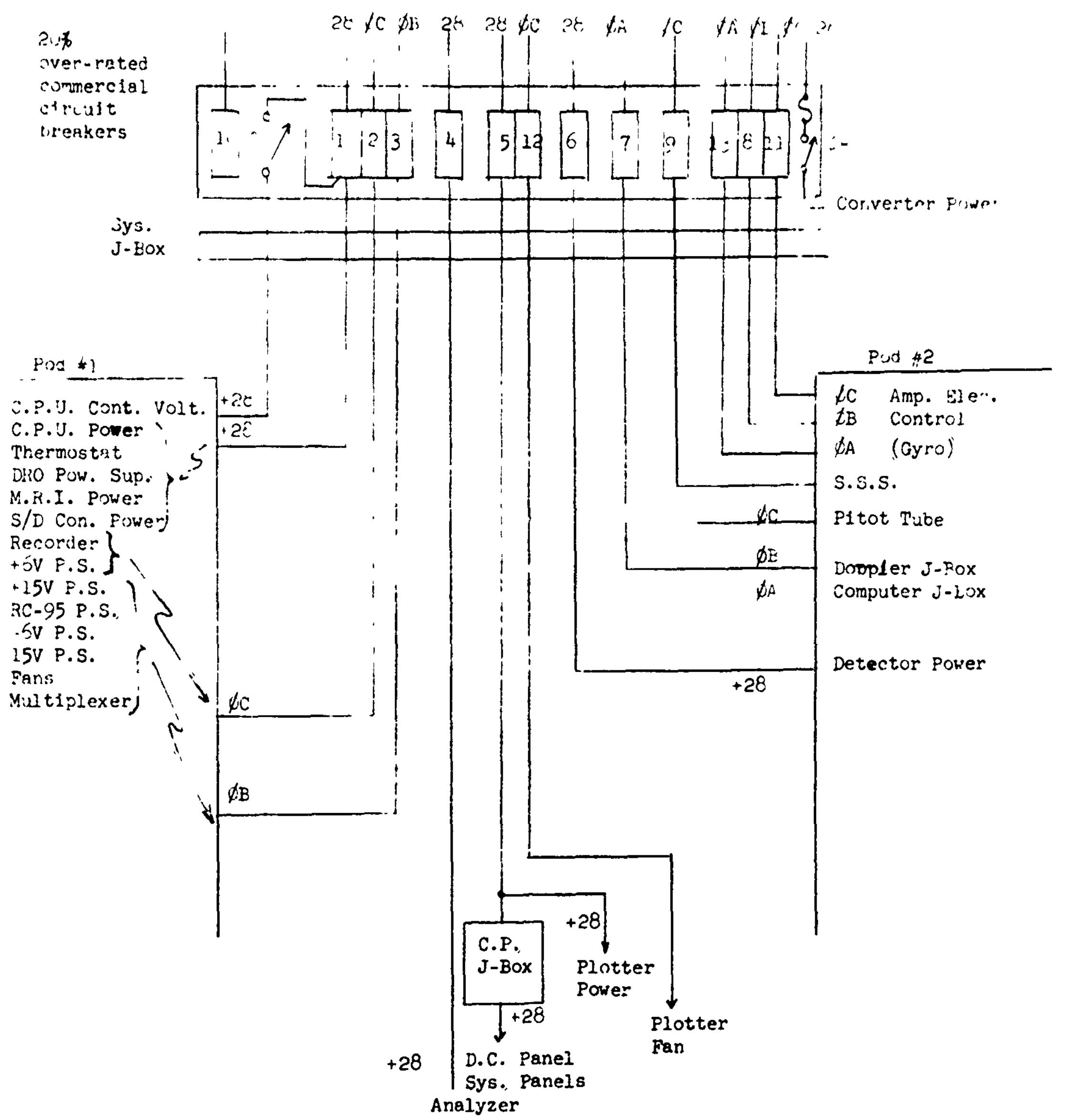


Figure 3-21. Power Panel Circuitry.

The loading of the system inverter has the following characteristics:

Inverter load is nominally

Phase A 5.52 amps
Phase B 3.08 amps
Phase C 3.52 amps

This balance is obtained with the pitot tube and side slip sensor heaters off.

Phase A is a much larger load because navigator gear in Pod 2 requires single phase A.

When heaters are turned on, loading becomes:

Phase A 5.52 amps
Phase B 4.78 amps
Phase C 5.02 amps

This amperage represents 71 percent of full load, and the inverter will draw approximately 15 amps after warm-up. When heater power is not required, balance improves. The characteristics of aircraft 28vdc power follow (this aircraft-generated power conforms to MIL-STD-704B, which specifies a voltage range that takes into account the line drop of power distribution.)

MIL-STD-704B	22.5-30vdc
Aircraft system voltage	24.5-30vdc
2Vdc line drop	-2v
MIL-STD-704B	22.5v-30vdc

The power subsystem has been designed to keep power line voltage drop < 2vdc and conform to MIL-STD-704B.

Transients: The dc aircraft 28V power can have transients:

± 600V for <50 usec

Filter: The 28VDC MS244981 battery is across the aircraft and acts as a filter.

$C_B = 0.001$ farad

This should effectively shunt this transient if it should occur.

Load: The inverter 115a
The system units 32.8a min/nom
54.8a max/surge

The 28-volt power is brought to the power panel along with 400-cycle 3ϕ 115v inverter power for distribution (see figure 3-21).

The power panel consists of 13 circuit breakers and two switches, to route and control power to different sections of the AMPD-224 system; it is located behind and between the pilot and the copilot. The following control is included in the power panel:

3.3.8.1 Pod 1. Pod 1 power is controlled by CB1, 2 and 3. These CB's are ganged, and all Pod 1 power is applied at once.

S1—provides separate control of the CPU control voltage; it must be turned On/ Last and Off/First or the memory may be wiped out (the cause of this had not yet been determined). No interlock is provided.

CB10 is the 5-amp CB for starting the Leland inverter which can be turned on only after the aircraft engines are running. (*See FBD No. 3 and No. 3A for AMPD-224 changes in the control of power distribution.)

3.3.8.2 Pod 2. Pod 2 power is controlled by:

CB6 controls the detector power/separate lines are run for the detector circuit power and the detector pump power to reduce the effect of the pump surge.

CB7—Navigator

CB9—Heaters in the SSS and the pitot tube.

CB13, 8, 11—Compass power/2-1/2 minute warmup for gyro.

3.3.8.4 Cockpit.

CB4—Analyzer power

CB5, 12—all other cockpit power

3.3.8.5 Pod Power Distribution. Power is distributed in the pods from two terminal boards, one for (hi) side of power distribution and one for all returns.

NOTE: D-C and A-C returns are kept separate in the pods and brought to a common point only at the system J-box.

With the aircraft power at 28vdc and 115v, 3ϕ, 400 cycle the deliverable voltage to each piece of equipment is shown in table 3-12.

The average a-c power line drop is approximately 1 volt. The Leland inverter should be adjusted to 116 volts, for minimum variation from 115vac.

The d-c voltage drops conform to MIL-STD-704 and the dc can be 22.5vdc—30vdc.

Primary lighting power is obtained from the aircraft lighting bus and routed directly to the systems panel.

3.3.8.1 System Junction Box. The system junction box (unit 13) comprises the system interface between the power panel and the AMPD-224 system. All signals into and out of the aircraft will be brought through the J-box. The junction box is a three-high type 2 configuration, utilizing the type 2 pins for the programing of functions. Type 3 connectors bring the signals into and out of the junction box. The junction box is located in the aircraft baggage compartment.

3.3.8.2 Pylon Connectors (ITT Cannon). The characteristics of the pylon connectors assembly follow:

1. The pins are in the plug side of the assembly. This assembly contains one 24-31 insert and four 24-61 inserts.

TABLE 3-12. DELIVERABLE VOLTAGES

Unit	Current Amps	V Drop	V Deliv
200	1.9 ϕA	1.722 vac	113.278v ϕA
209	1.5 ϕC	1.040 vac	113.960v ϕC
203	3.3 ϕA	1.586 vac	113.414v ϕA
214	0.04 dc	.474 vdc	27.526 vdc
215	1.7 ϕB Nom	.956 vac	114.044v ϕB
	4.0 ϕB Max	1.730 vac	113.270v ϕb
206	0.4 ϕC	.791 vac	114.209v ϕC
	0.4 ϕB	.680 vac	114.320v ϕB
	0.4 ϕA	.809 vac	114.191v ϕA
211	1.0 dc	1.013 vdc	26.987 vdc
212	Ckt		
213	Power		
211	1.0 dc	1.076 vdc	26.924 vdc
212	Pump		
213	Power		
211	2.2 dc	2.163 vdc	25.837 vdc
212	Pump		
213	Surge		
1A1	No load as of 23 Sept 67		
1A2	0.16 dc	0.708 vdc	27.292 vdc
2	1.2 dc	0.449 vdc	27.551 vdc
12	4.0 dc Nom	969. vdc	27.031 vdc
	5.0 dc Max	1.173 vdc	26.827 vdc
3	4.0 dc Nom	0.578 vdc	27.422 vdc
	15 dc Max	1.721 vdc	26.279 vdc
102	6.0 dc Nom	0.896 vdc	27.104 vdc
	11.0 dc Max	1.223 vdc	26.777 vdc
103	9.0 dc	1.067 vdc	26.933 vdc
	1.0 dc	0.799 vdc	27.201 vdc
100	0.3 dc	0.795 vdc	27.205 vdc
106	1.25 dc	0.910 vdc	27.090 vdc
105	1.5 ϕC	1.175 vac	113.828v ϕC
120	1.5 ϕC	1.172 vac	113.828v ϕC
118	0.1 ϕB	0.946 vac	114.054v ϕB
108	0.2 ϕB	0.969 vac	114.031v ϕB
121	0.2 ϕB	0.969 vac	114.031v ϕB
119	0.5 ϕB	1.040 vac	113.960v ϕB
Fans	1.5 ϕB	1.275 vac	113.725v ϕB
107	0.26 ϕB	0.985 vac	114.015v ϕB

2. The sockets are in the receptacle side of the assembly. This assembly contains one 24-31 insert and four 24-61 inserts.

3. The lanyard force necessary for activating the ejection mechanism will be 15 ± 5 pounds at zero angle of pull. At right angles, the force will not exceed 35 pounds.

3.3.9 Computer Program

It was decided in June, 1967, that the 7044 computer would be used (due to memory capacity problems in the 205 computer) for developing and assembling the Mk 12 Program.

In August 1967, both the Phase IV Mk 12 Assembler and Mk 12 Simulator programs were completed on schedule. The assembler was in full use producing tapes.

A software implemented checkout procedure for the data handling subsystem was recommended similar to that being used on Phase II. The required additions to the digital control panel to implement this checkout method were accepted by Systems Engineering. In November, 1967, an improved sum check and sum check tester were added to the program, and the program size reduced by 10 percent through deletion of sub-routines no longer required (size of program: 3400 words). By December, 1967, effort had been initiated by Engineering computations to add sum check capability into the assembler. A sum check routine was also being added to the tactical program. Effort had also been expended to reduce the size of the tactical program, which currently utilized about 70 percent memory with a resulting saving of about 2 percent of memory to date.

Software changes had also been made in the following areas:

1. Plotter drive sequence (to correct for slow speed Mk 12 output circuits).

2. Cube root routine.

3. Math models 1, 2, and 3 to correct short offsets situation.

The Mk 12 simulation program (7044) was being used to debug software problems due to lack of any Mk 12 computers on the bench. To be completed was the decimal display program. By January, the Short Offset software operation was proven satisfactory except for math model 3, which did not always iterate to a proper solution.

Current reprogram effort was concentrating on:

1. Correct offset in all 3 math models.

2. Improved iteration capability in math model 3.

3. Initial decimal display program.

In March, 1968, System 2 was utilized for a thorough checkout of the Corrected Offset program. A large number of plots were made for each math model with excellent results. This represented a major step in providing operational software for Phase IV aircraft.

Systems 1 and 2 were software compatible at this time. Corrected Offset version of tape was checked out in OP 8 test berth prior to shipment.

By April 1968, the 7044 data readout program was improved to provide better printout of tape records.

Software documentation effort continued. Drafting had been given several program flow charts and requested quotes on this effort from a subcontractor.

In May, a new math model had been incorporated into the program to be used in the Florida flight tests. A program to perform analysis of detector signals was also utilized during the flight tests.

In June 1968, incorporation of the new math model and pulse analysis routing were required for the OV-1 which spent a week at Pittsfield airport for debugging and program test. The OV-1 left for Florida test 28 Jun 68 with a tape containing all three changes. At this point, all data handling equipment and software appeared to be operating satisfactorily on both aircraft with the exception of DISCON decimal display software. The latter was currently being checked out in the lab.

In July, during the test period, improved program tapes were assembled and forwarded to OV-1 and C-47 personnel to correct minor problems. During September 1968, preliminary tests were run on the variable source size program. Effort continued on the new pulse analysis program and Fortran simulation of the new program. Tapes were received from Fort Huachuca for Fortran processing. Additional funding was received from the customer to support this effort through December 31, 1968.

In October, effort continued on the new pulse analysis program and its Fortran simulation. Initial simulation results were forwarded to OP 8 and Ft. Huachuca. Initial checkout of the pulse analysis program on the aircraft showed up some real-time conflicts which were currently being reworked. Simultaneous effort was carried on to check out the source—guess program on the OV-1. Results were good in the directional sense and the double-plot functioned reliably. However, several discrepancies were apparent between the calculated answer and the resulting plotter and DISCON displays.

A concurrent investigation was being carried on to identify the scope of change involved in adjusting the math model to a new turbulence range.

In November, 1968, remaining Fortran simulation results for the new pulse analysis program were forwarded to Fort Huachuca. Additional aid was given to Fort Huachuca personnel to enable them to set up a local tape readout facility.

The Mk 12 pulse analysis program was completed, including bench checkout and aircraft checkout, all with good results. The integrated pulse analysis/math model tape was checked out for use in field tests.

Bench retest was completed on S-guess software with good results. Plotter and DISCON discrepancies have been partially accounted for and the current S-guess mechanization will be utilized in upcoming field test.

Scope change for the new turbulence range had been identified and the nature of the change had been judged by the Project Management to be too complex for immediate incorporation into the program.

Documentation effort continued in both the control and math model areas on a part time basis.

3.4 SYSTEM FABRICATION

The wiring running lists were generated as information became available and started the later part of April, 1967. By early August, 1967 the Pod 2 running lists were essentially complete as were most of those for the aircraft. Pod 1 running lists were delayed due to emphasis on the Phase II data handling subsystem at that time.

In June, cable fabrication began. Pod 2 cables were built first and were used in bench cables for Navigator checkout in September, 1967. A minimum amount of rework was required when the cabling was transferred to the pods. To establish the proper lengths and routing, plywood pod mockups were constructed.

A portion of the Pod 1 cables were fabricated and used for bench checkout of the DHSS. The balance of the cables were fabricated and installed directly into the pod. Late in October and early in November, 1967, all cabling and equipment were installed in Pod 1 and checked out prior to start of system test.

A complete simulation of the AMPD-224 cockpit display, aircraft wiring using actual cable lengths, and a simulation of the aircraft power source using an inverter and aircraft battery were built in the laboratory at GEOS (figures 3-48 through 3-50); this allowed an early determination of system integration and interaction type problems within a controlled environment. The laboratory facility was completed in late October, 1967. Prior to receipt of the Leland inverter and the GE battery, house power was used for checkout.

A decision was made in late May, 1967 to include a system junction box. Its inclusion allows maintenance of subsystems signal flow between pods and between a pod and the aircraft. The system junction boxes and the cockpit junction boxes (figure 3-53) were fabricated at GEOS and installed in the aircraft by Gruman. Simulated J-boxes were fabricated to be used in the laboratory test setup.

Because pylon connector locations were not defined early enough, exit location for pod cabling was delayed. Pods were hard-wired to the system test setup. Following system test, the pylon connectors were installed and the system rechecked to pick up any wiring errors.

As System 1 cables were completed, System 2 cables were fabricated. The wiring was installed directly into the pods and checked out. Following shipment of System 1, System 2 was brought into the test area and checked out on the system test facility. The laboratory cables and Junction Boxes were later installed in the UH-1. Details of the pod wiring can be seen in figures 3-22 through 3-47.

3.5 SYSTEM TEST (SUMMARY)

The AMPD-224 system test was conducted at GEOS from 11 Nov 67, to 17 Jan 68. The system test results* follow.

3.5.1 Power Consumption Check

The power consumption of the various AMPD-224 subsystems was determined by measurement to ensure that proper selection of power panel circuit breakers and system wiring sizes had been made. The tests indicated that no potential problems existed.

*The system test procedures and all original data and results are included in Appendix A of this report

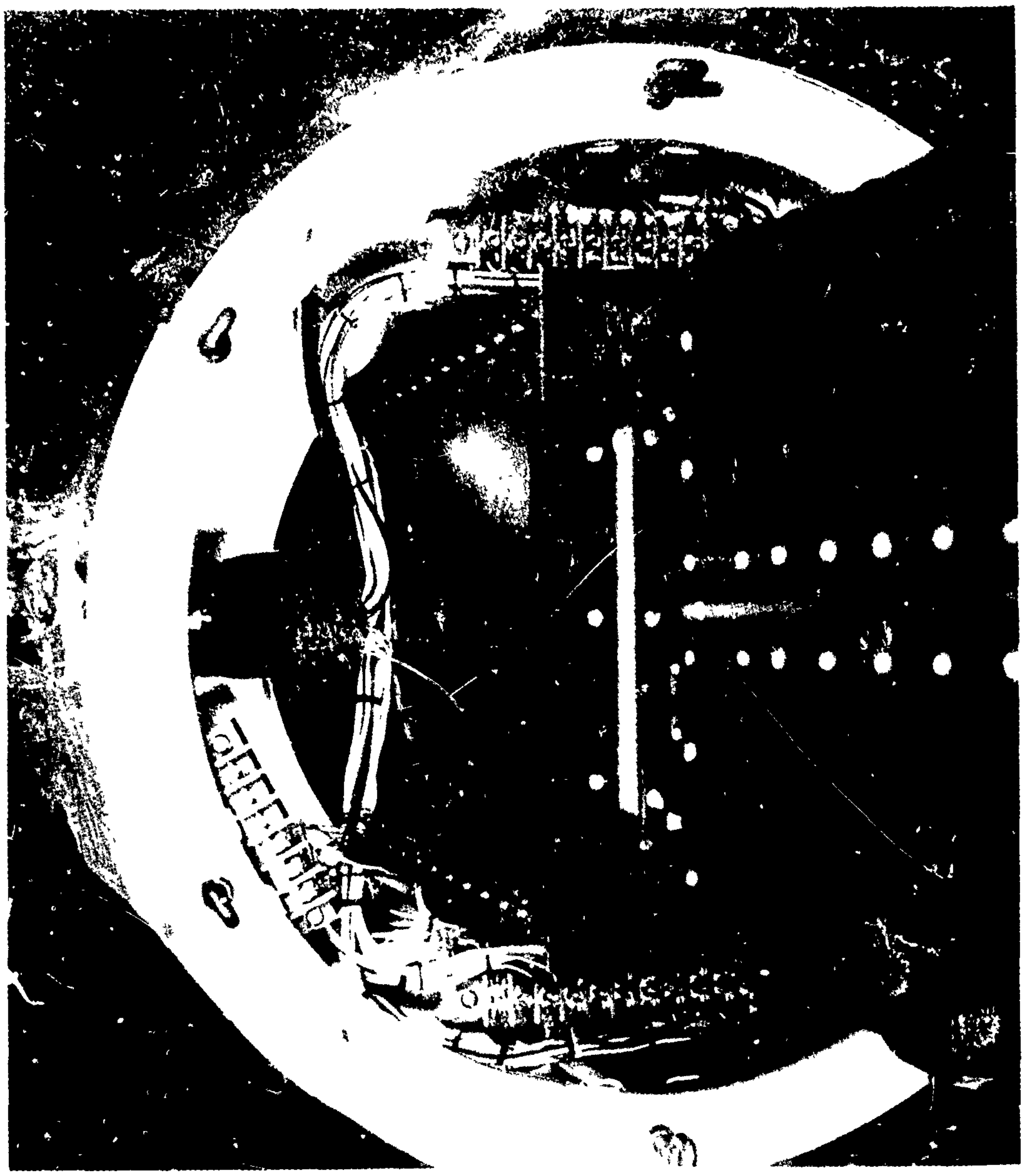


Figure 3-22. Pod 1 Forward Center Section Wiring (End View).

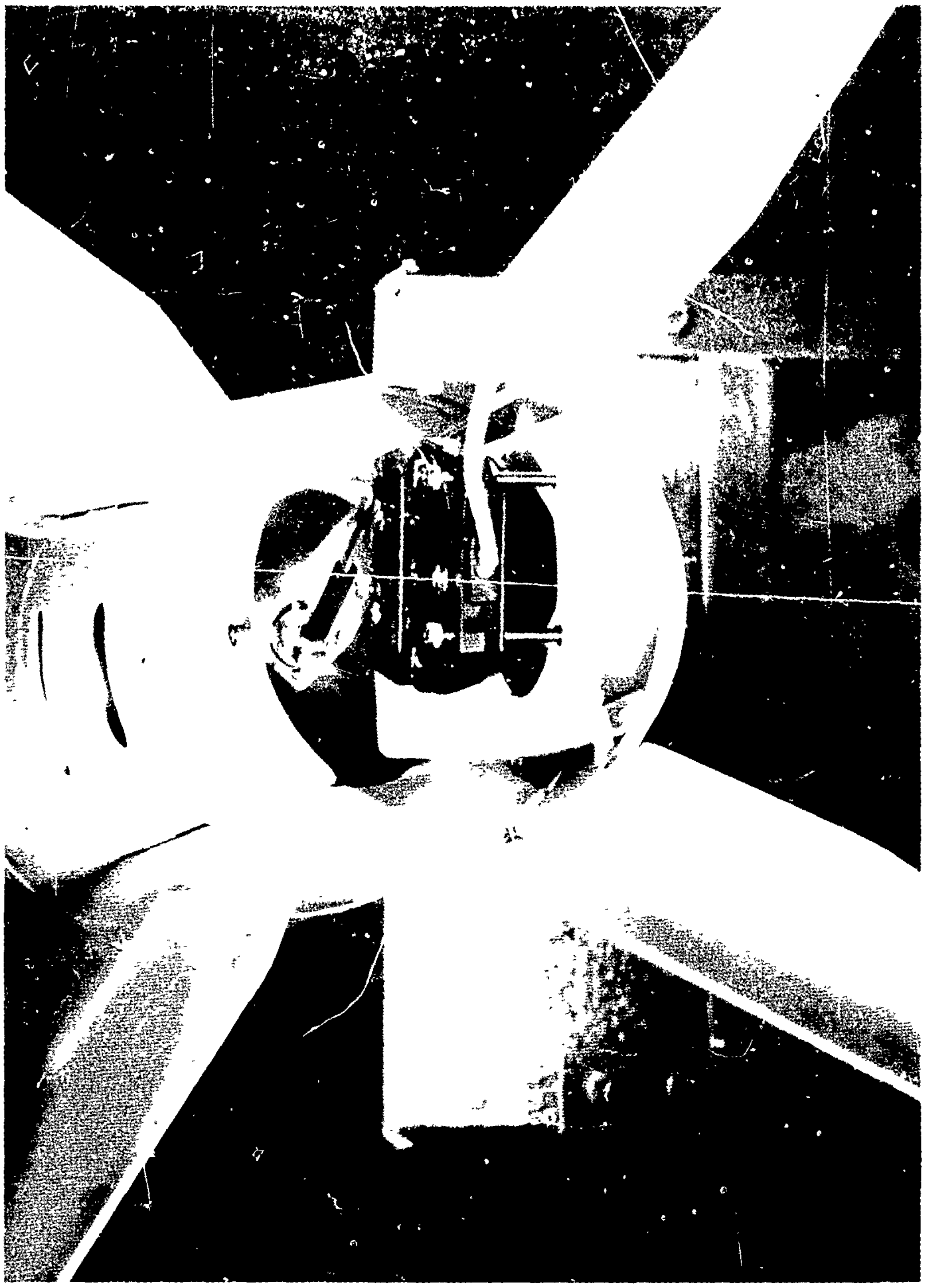


Figure 3-23. Pod 2 Tail Section—Magnetic Compass and Mounting Bracket.

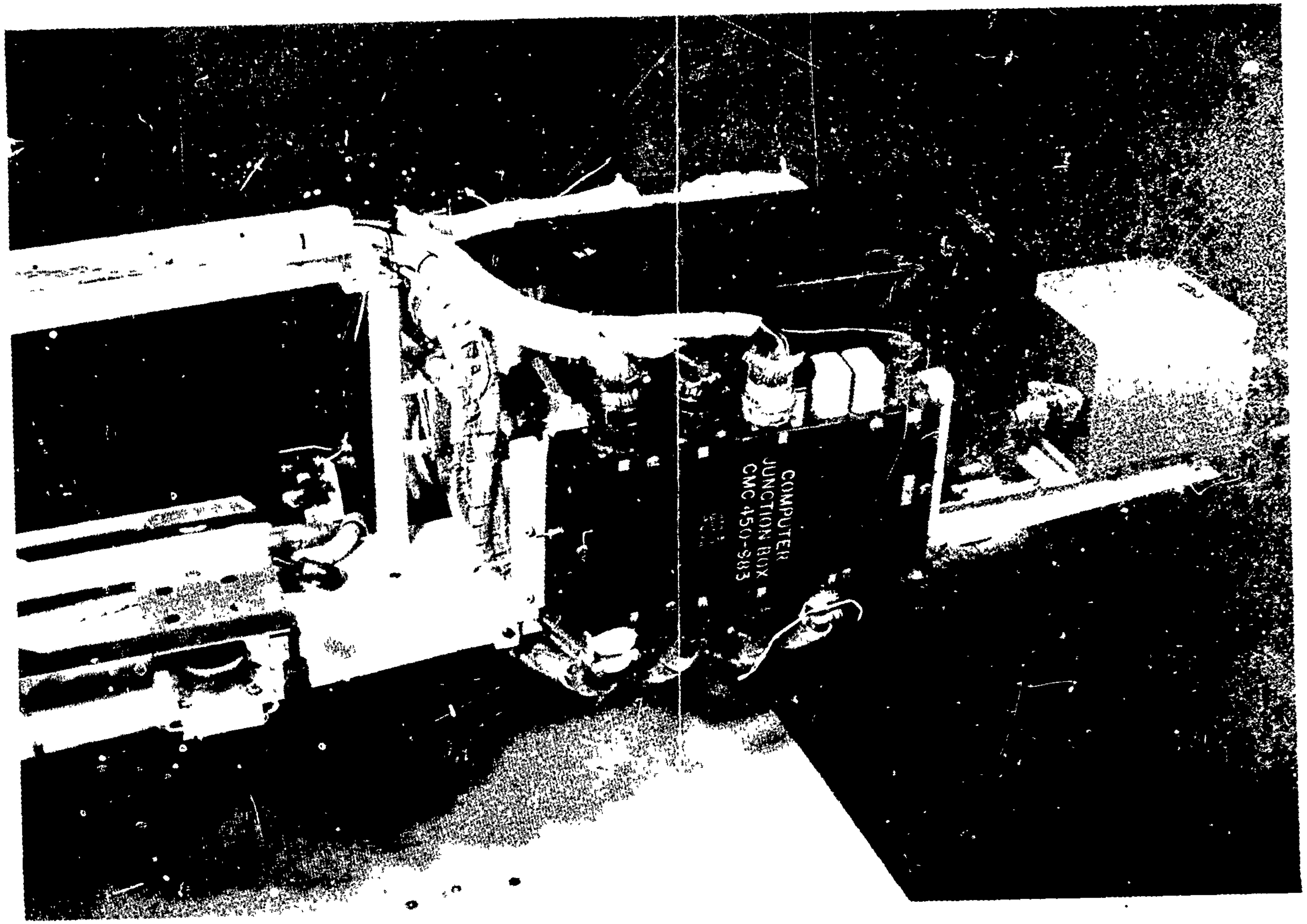


Figure 3-24. Pod 2 Aft Beam Section Wiring (View top Left).

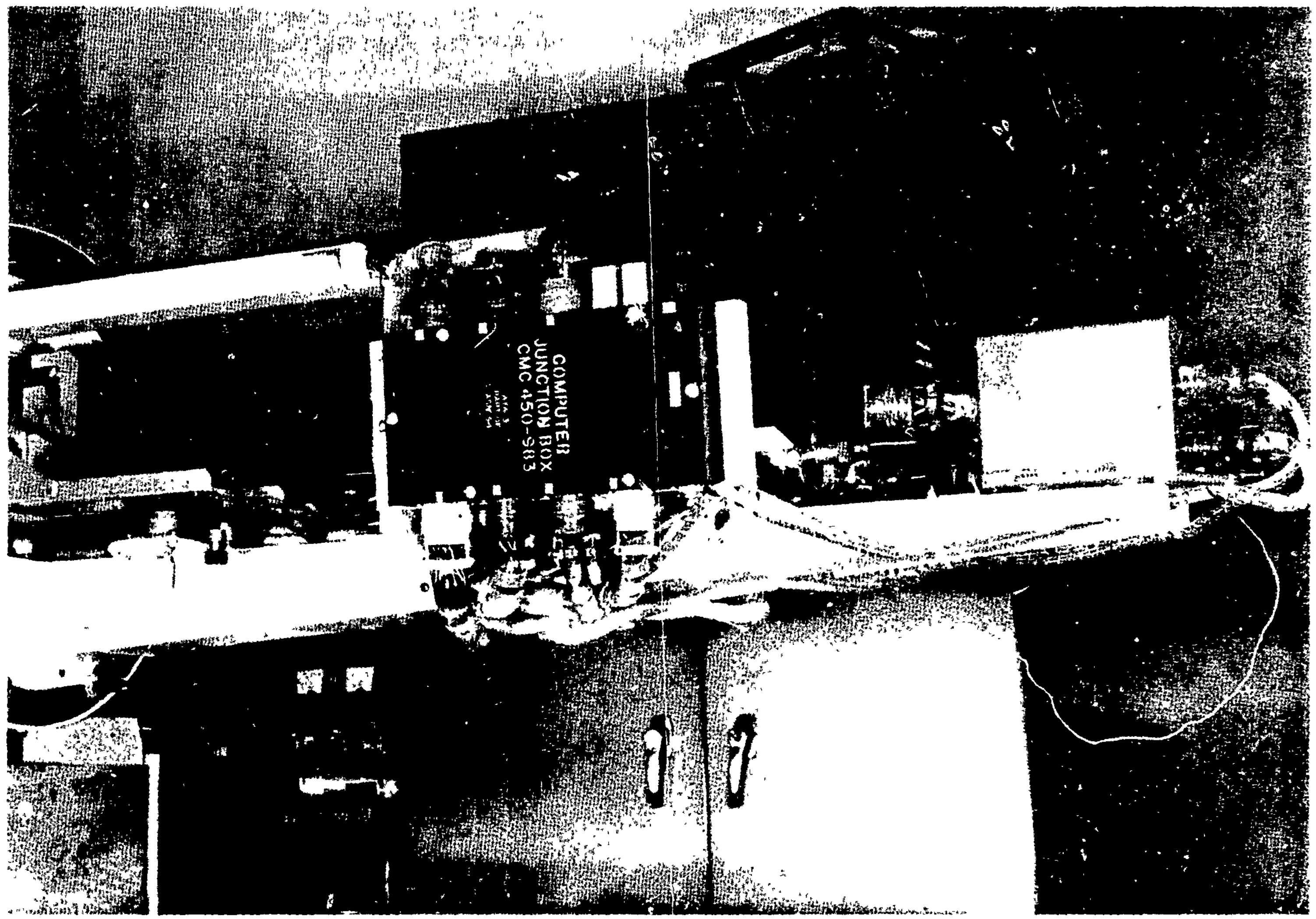


Figure 3-25. Pod 2 Aft Beam Section Wiring (View Left Side).

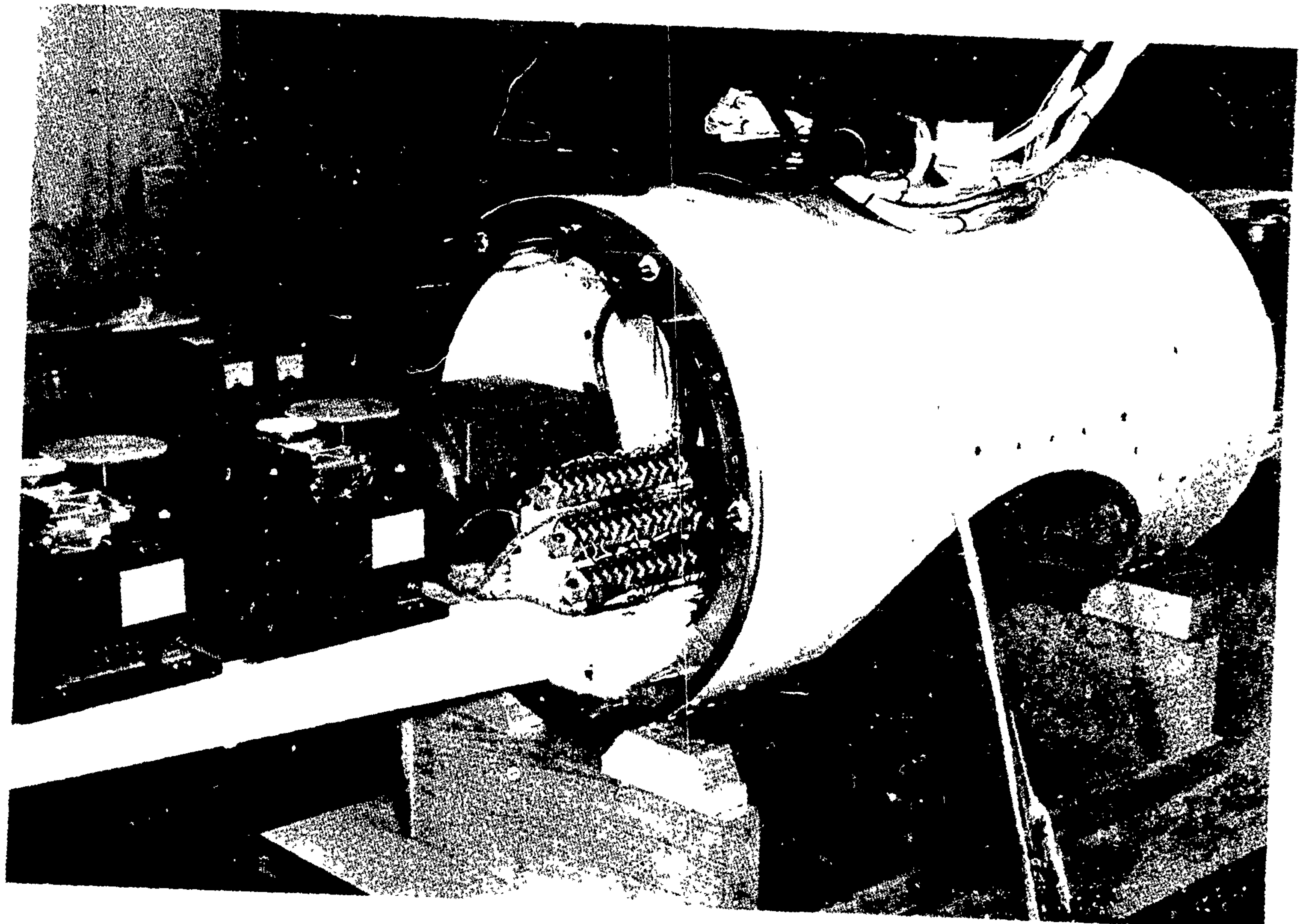


Figure 3-26. Pod 2 Center Section and Forward Beam Wiring (View Left Side).

Figure 3-27. Pod 1 Forward Beam Wiring (View Left Side).

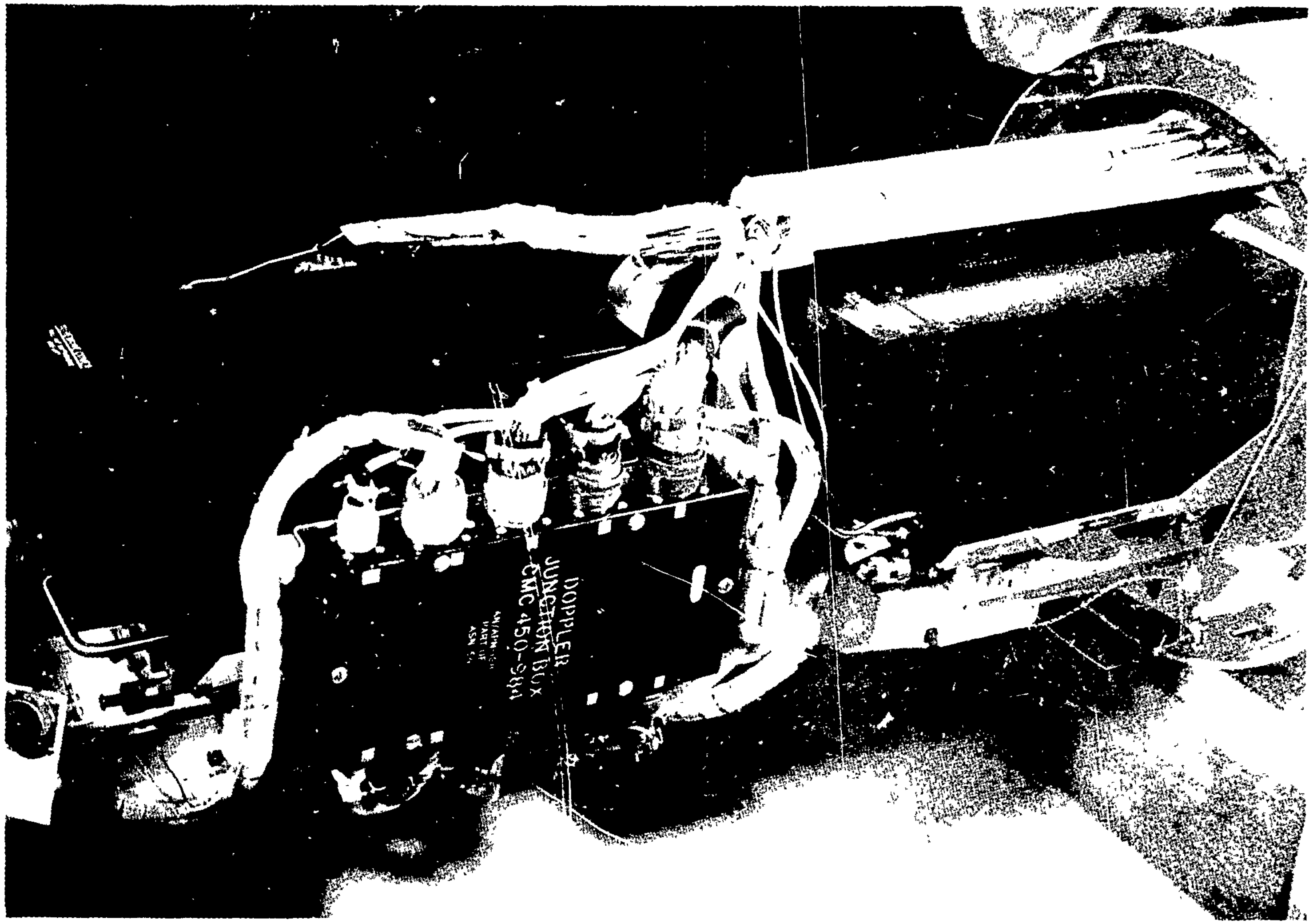


Figure 3-28. Pod 2 Aft Beam Wiring (View Top Right).

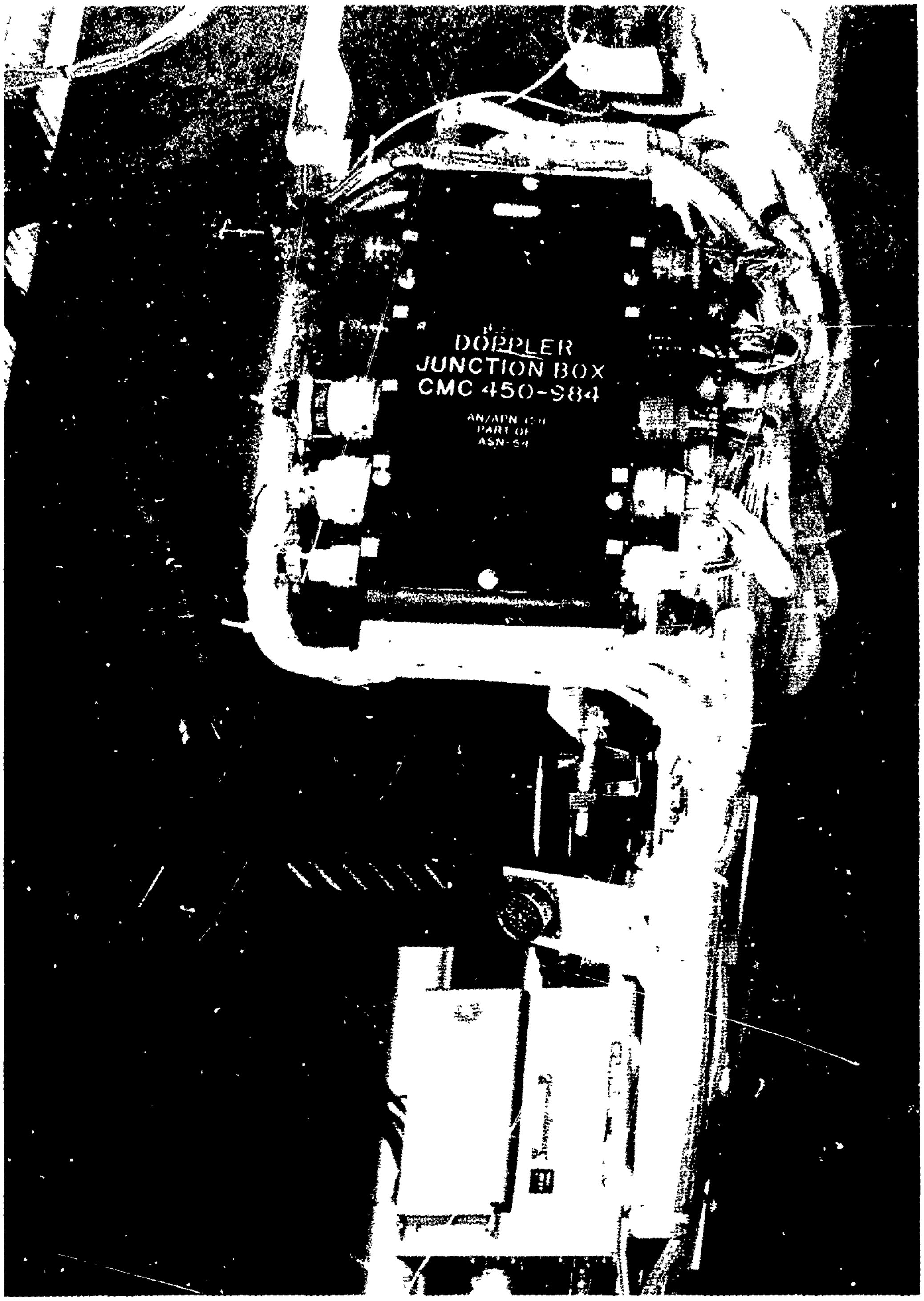


Figure 3-29. Pod 2 Aft Beam Wiring (View Right Side).

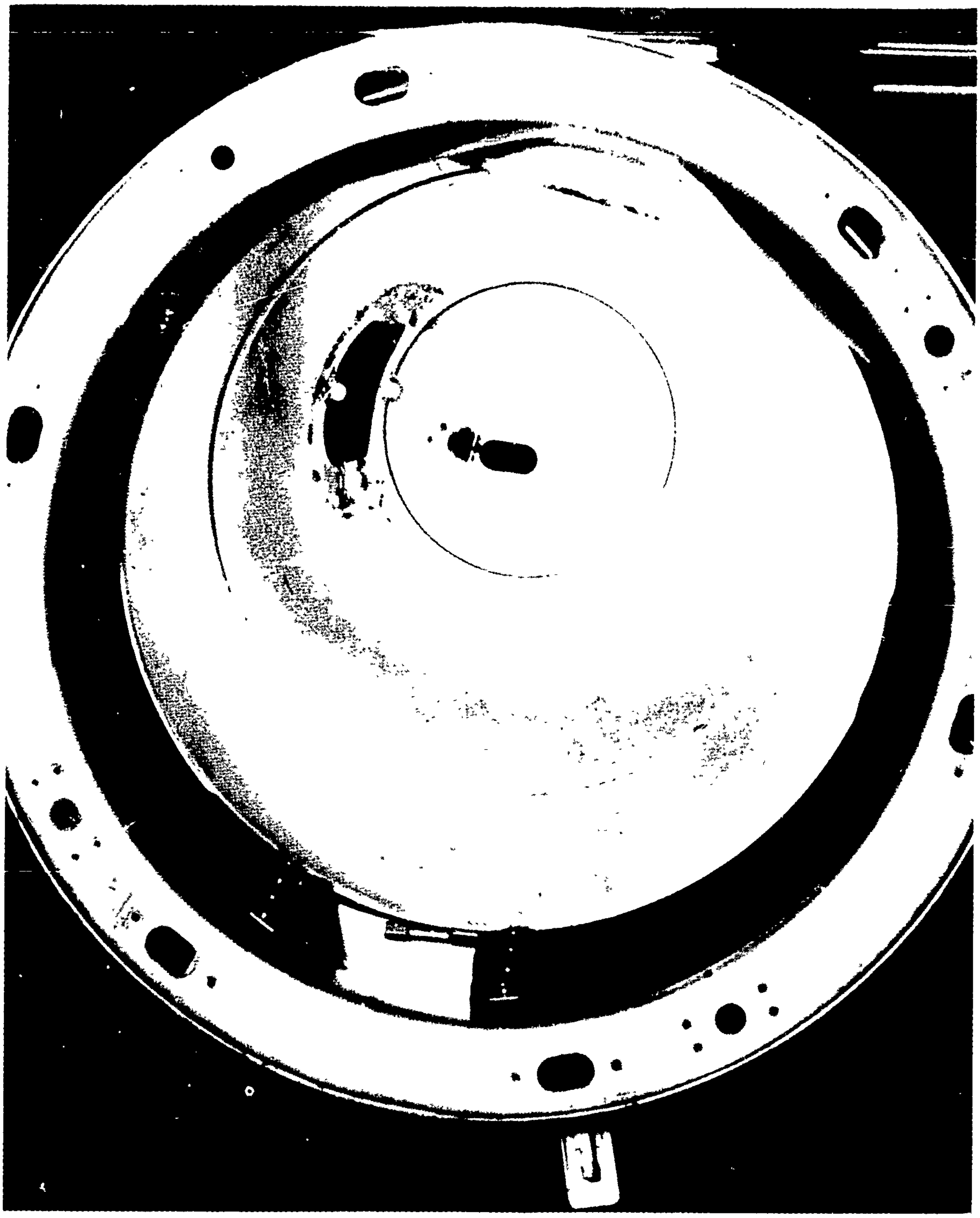


Figure 3-30. Pod 2 Aft Section (View Forward).

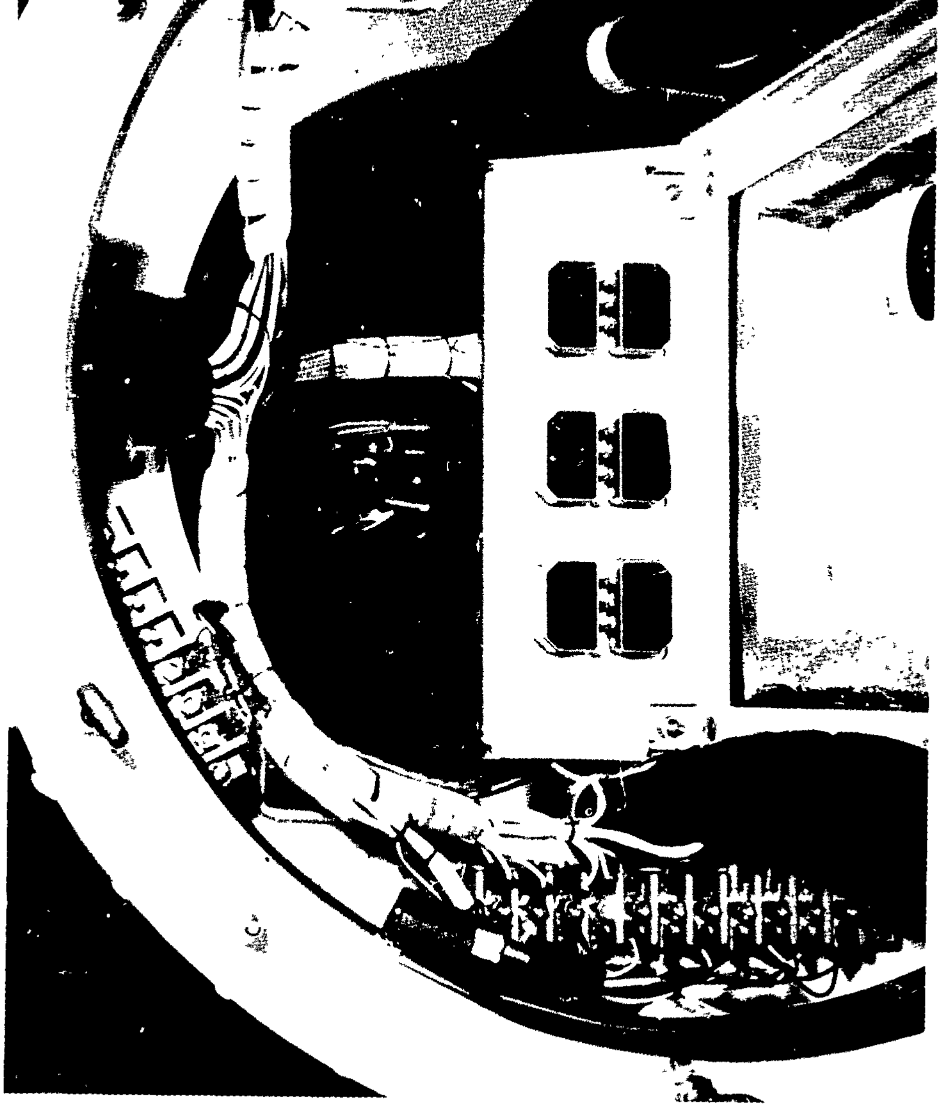


Figure 3-31. Pod 1 Center Section Wiring (View Forward).

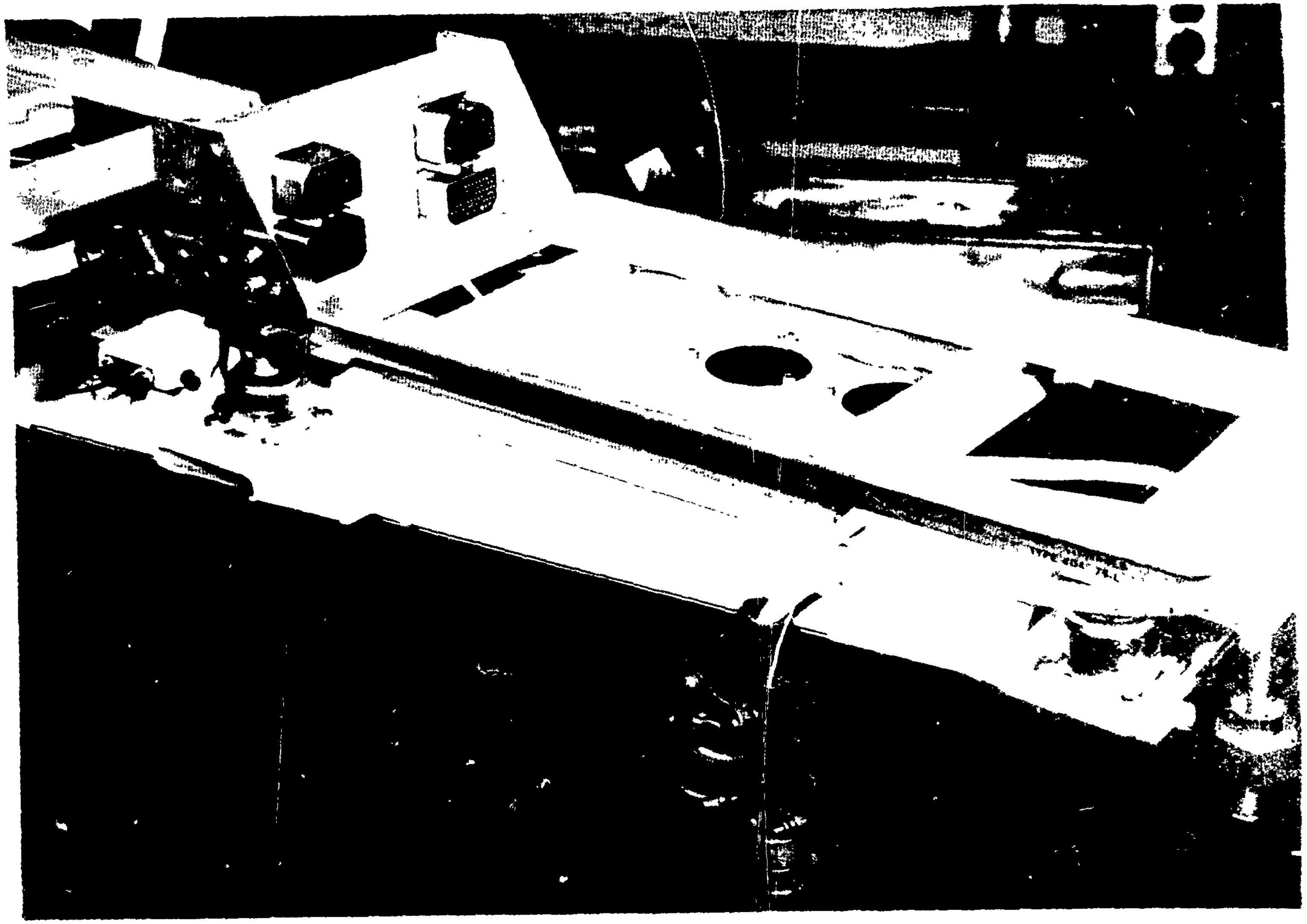


Figure 3-32. Pod 1 Forward Beam Wiring (View Top Right Forward End).

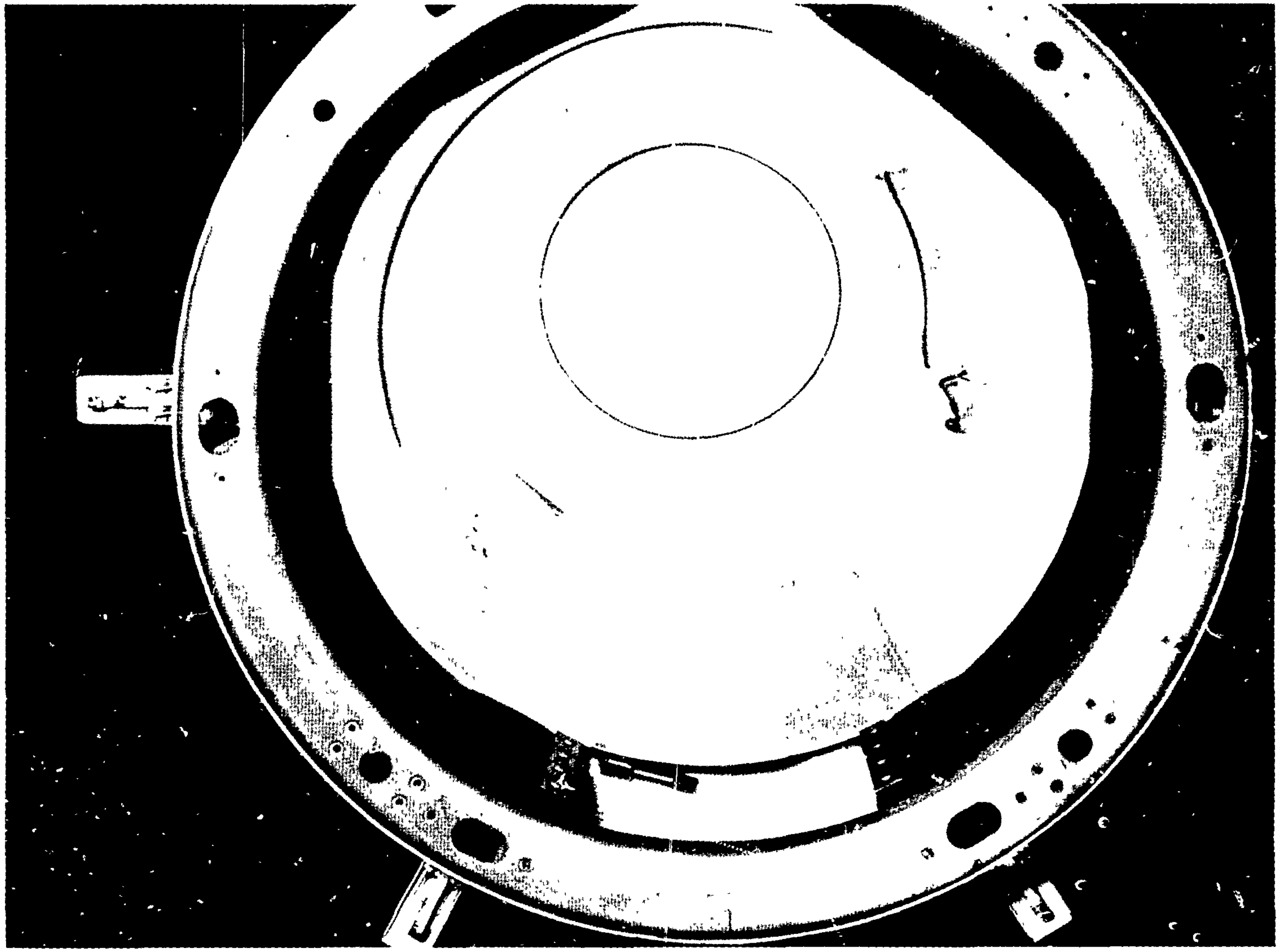


Figure 3-33. Pod 1 Aft End Section (View Forward).

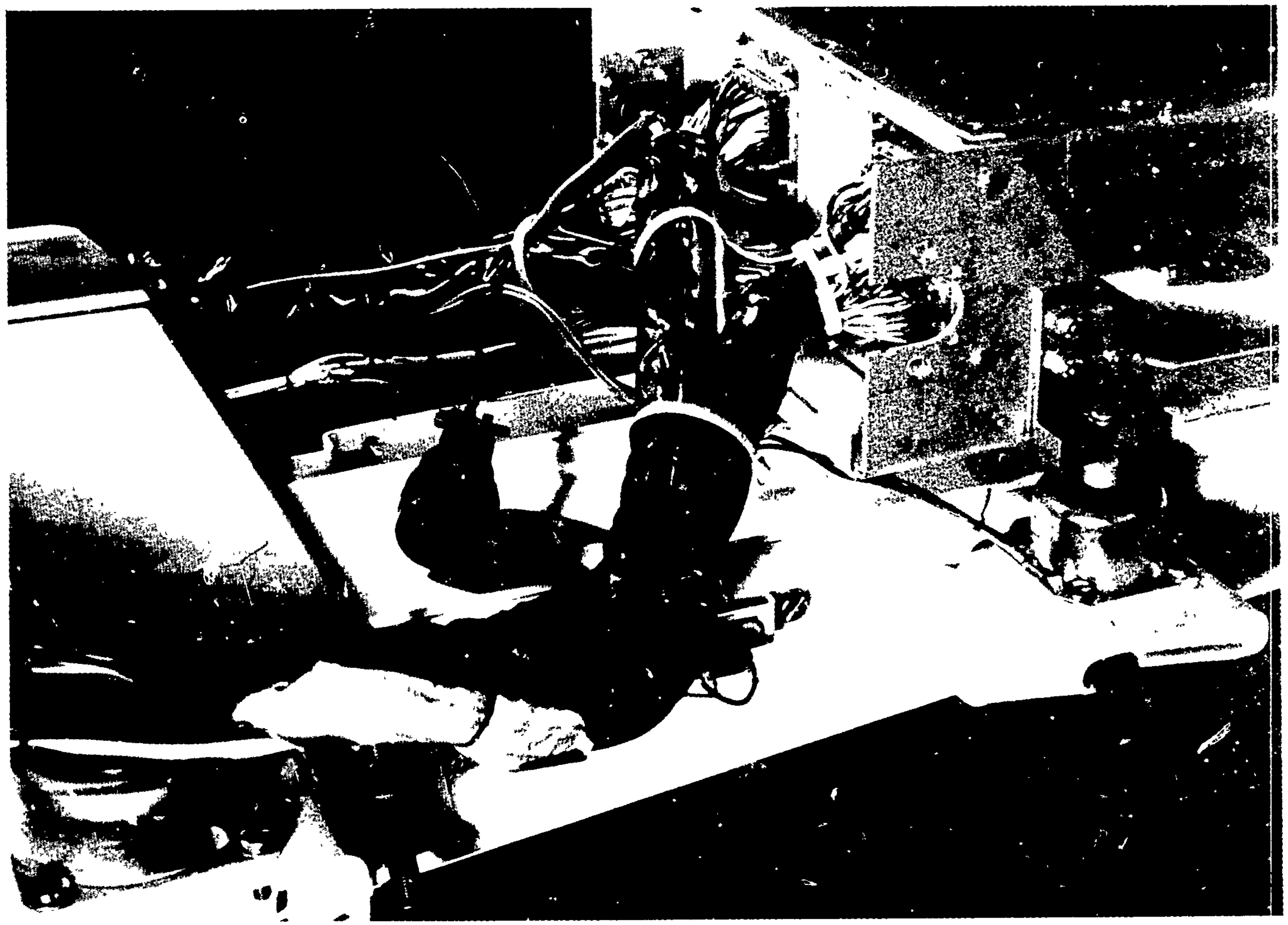


Figure 3-34. Pod 1 Forward Beam Wiring (View Top Right Middle Section).

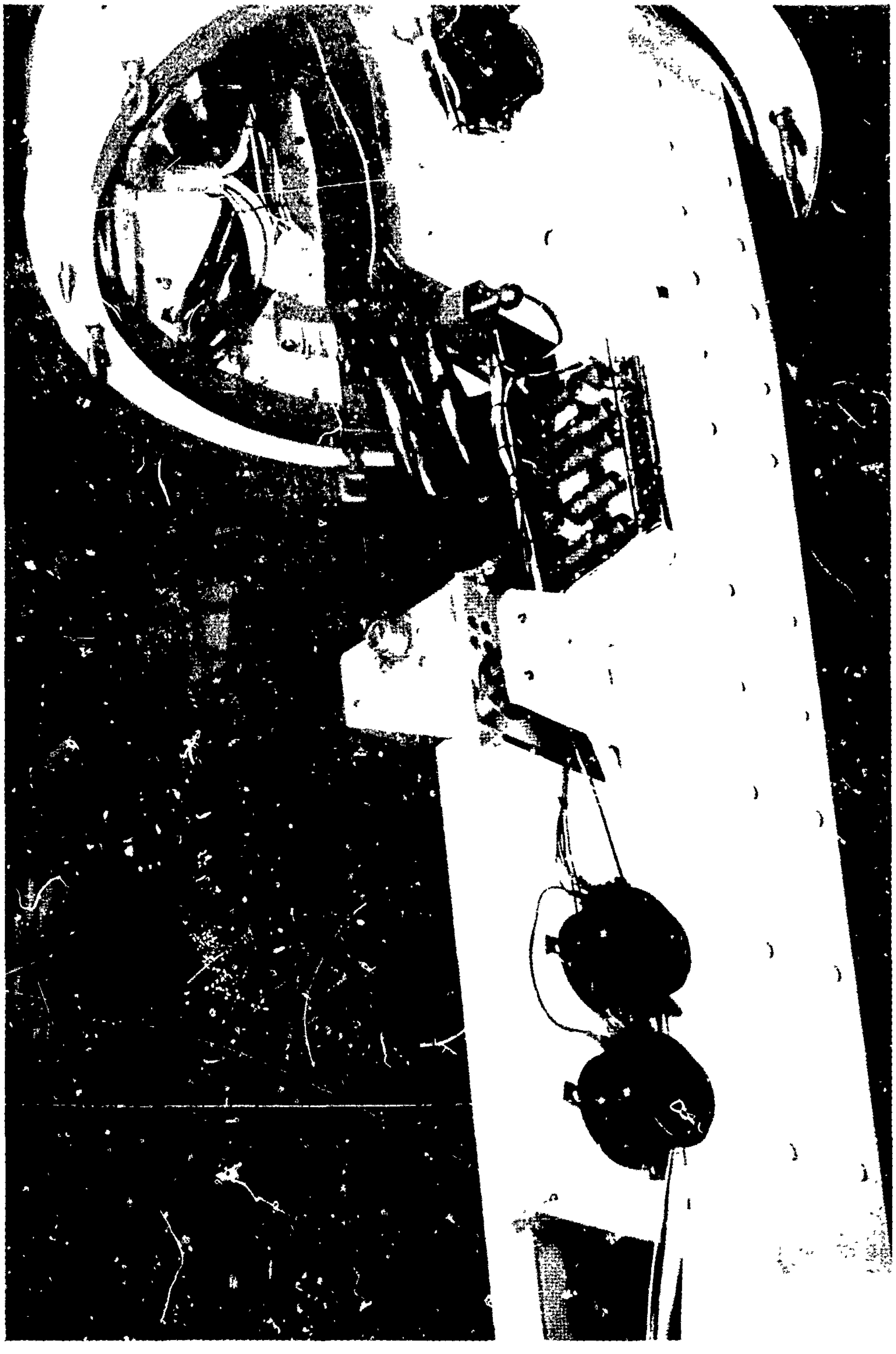


Figure 3-35. Pod 1 Forward Beam Wiring (View Bottom Left).

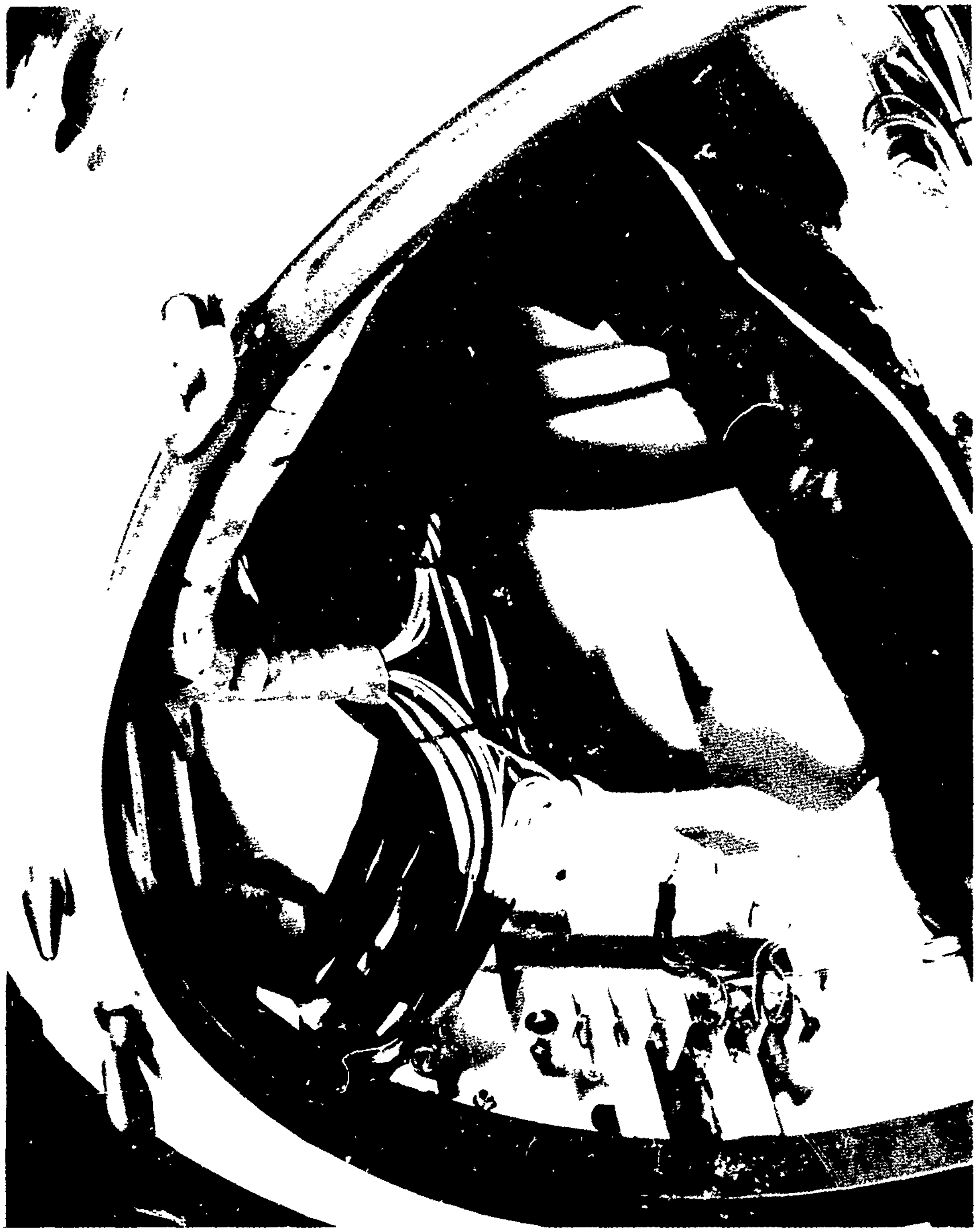


Figure 3-36. Pod 1 Center Sections Wiring.

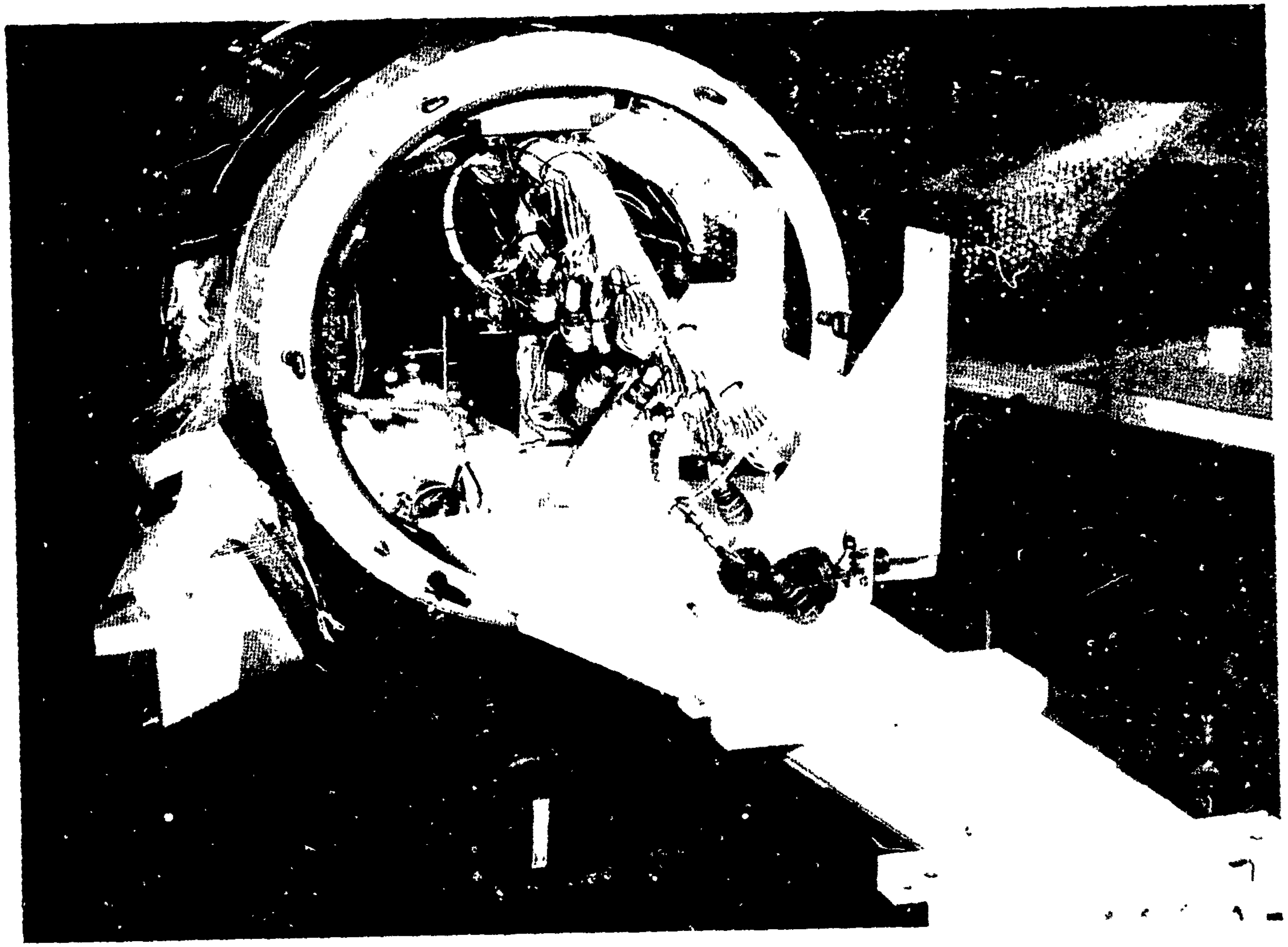


Figure 3-37. Pod 1 Aft Beam and Center Section Wiring (View Left Center).

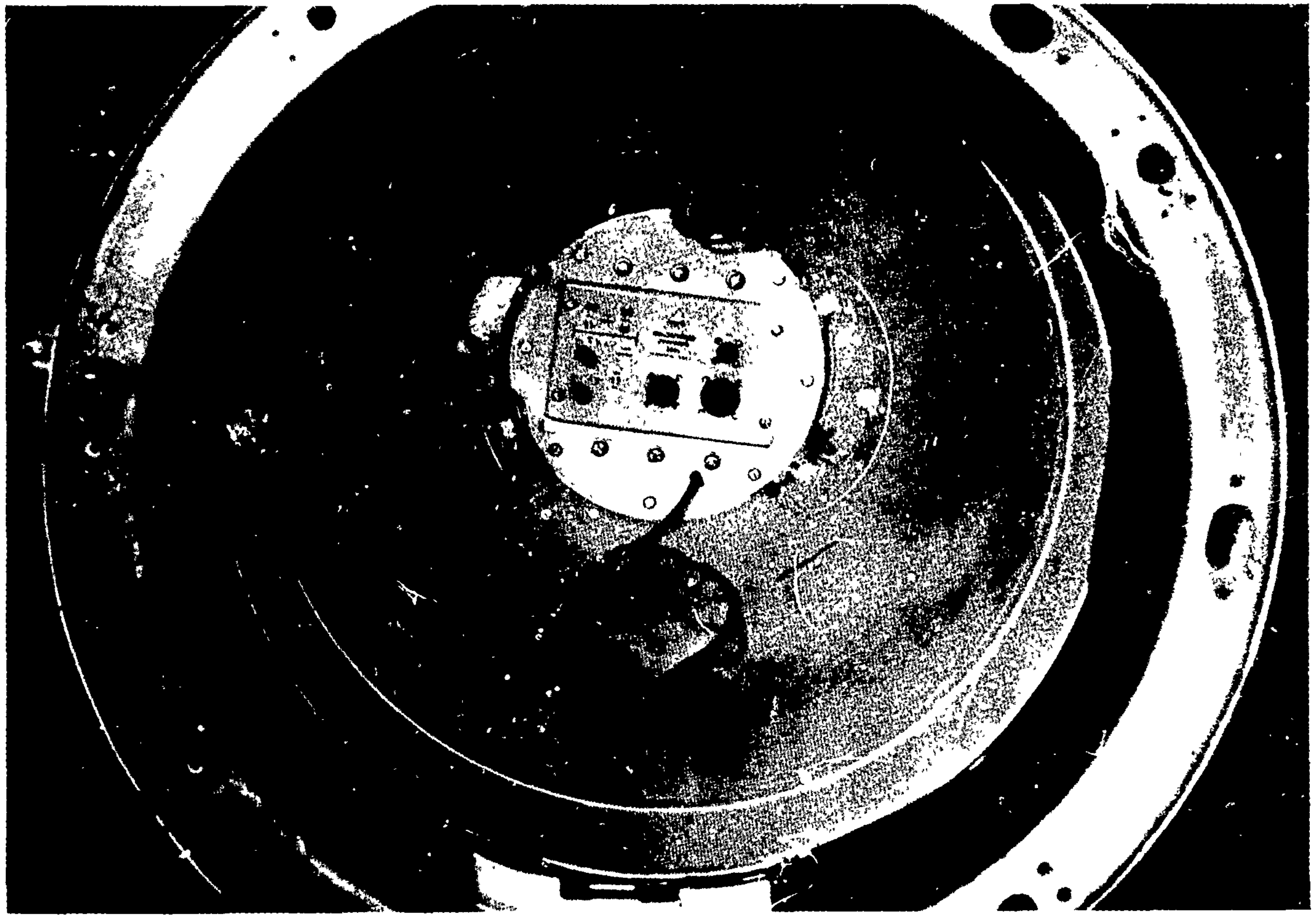


Figure 3-38. Pod 1 Forward End Section Wiring (View Aft End).

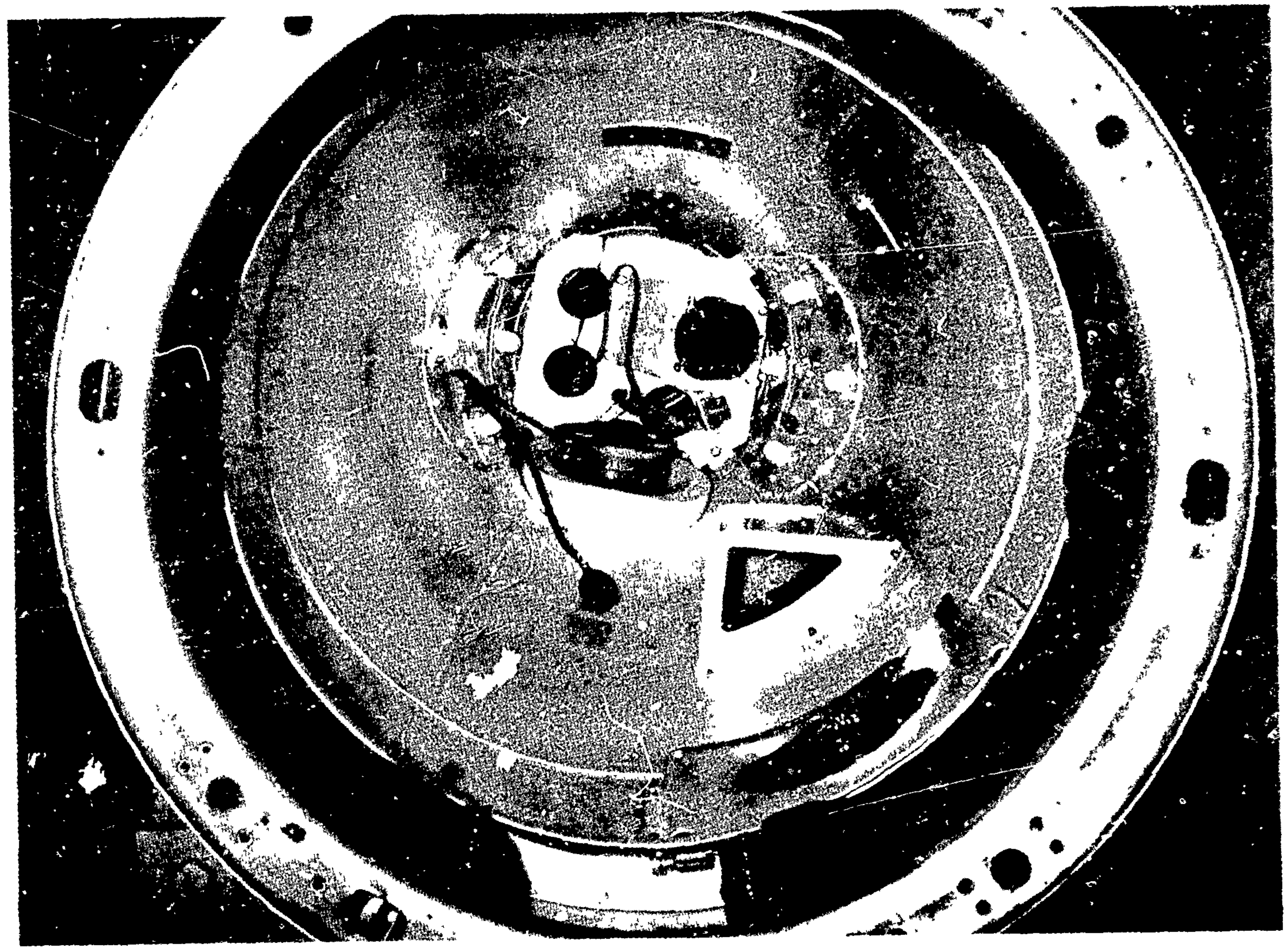


Figure 3-39. Pod 2 Forward End Section Wiring (View Aft End).

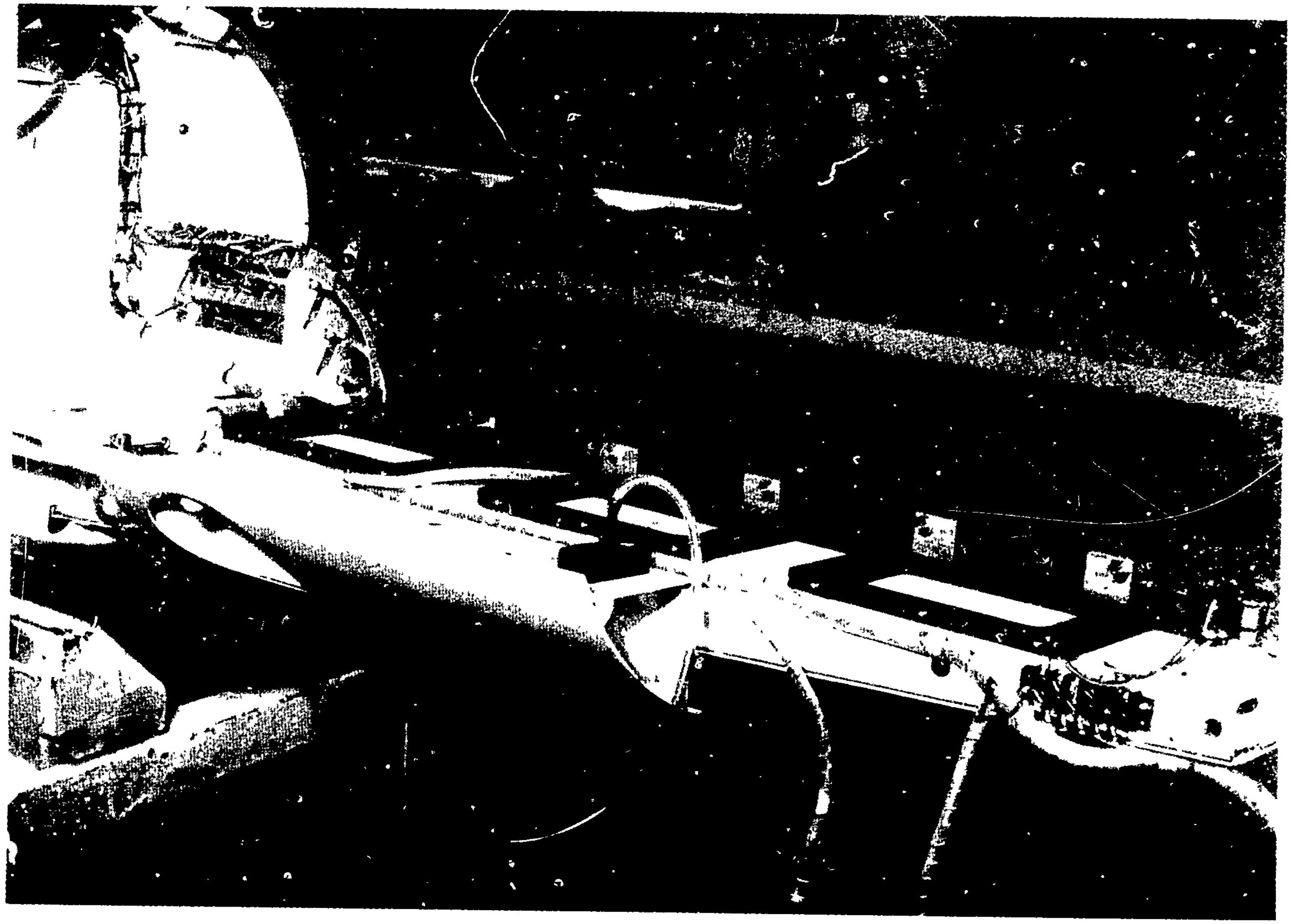


Figure 3-40. Pod 2 Forward Beam and Forward End of Center Section Wiring (View Right Side).

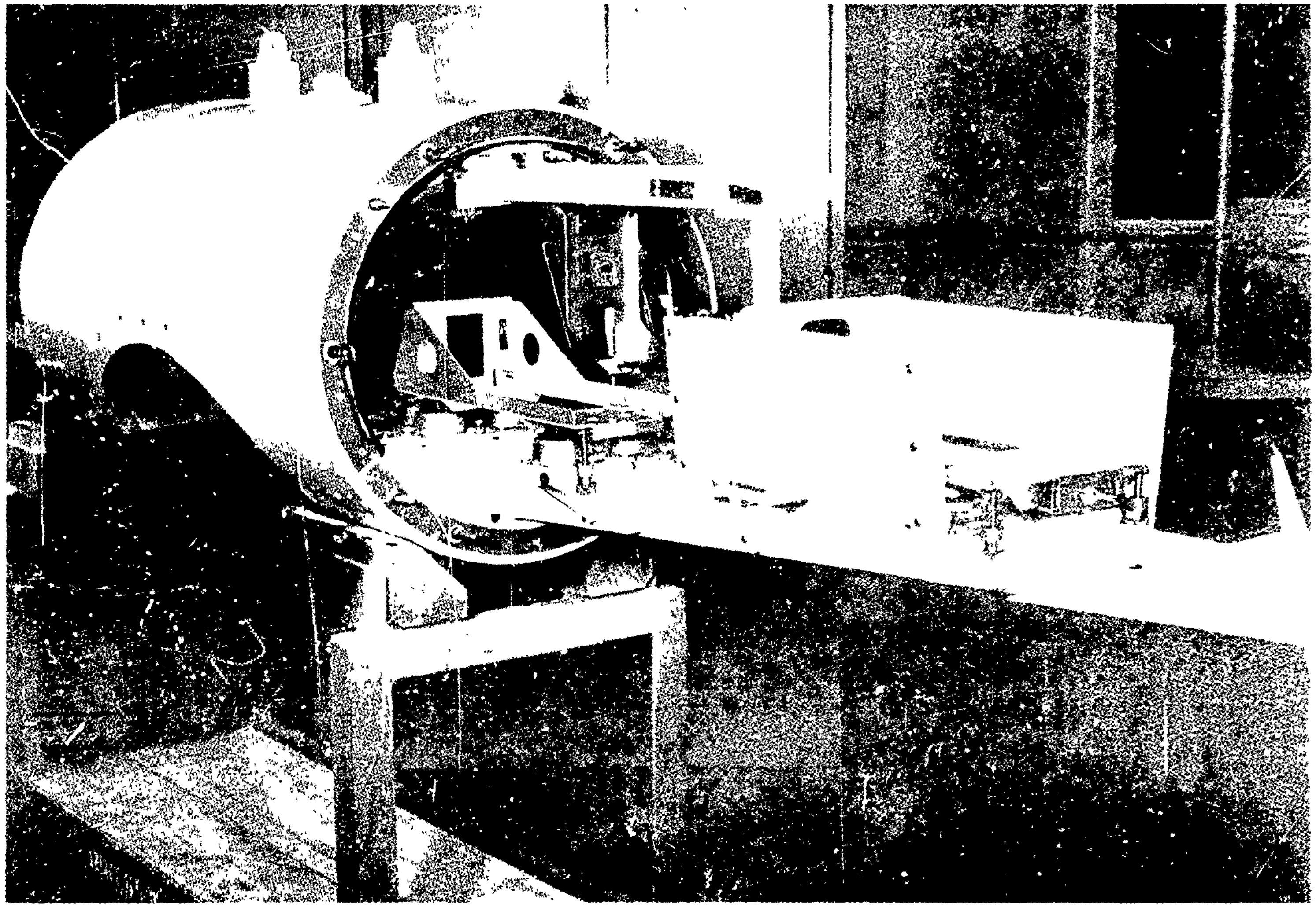


Figure 3-41. Pod 2 Forward Beam and Forward End of Center Section Wiring (View Left Side).

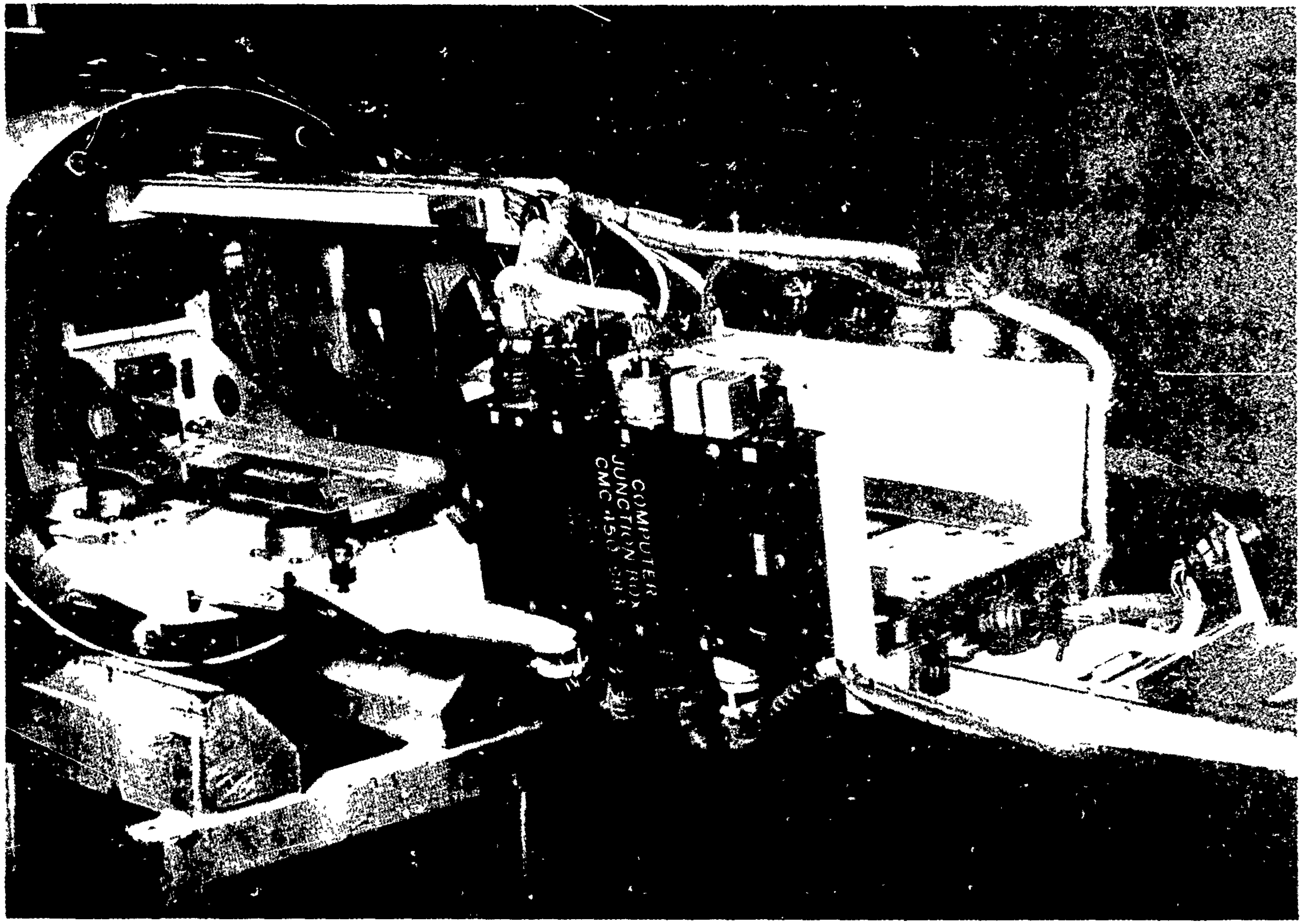


Figure 3-42. Pod 2 Aft Beam and Aft End of Center Section Wiring (View Left Side).

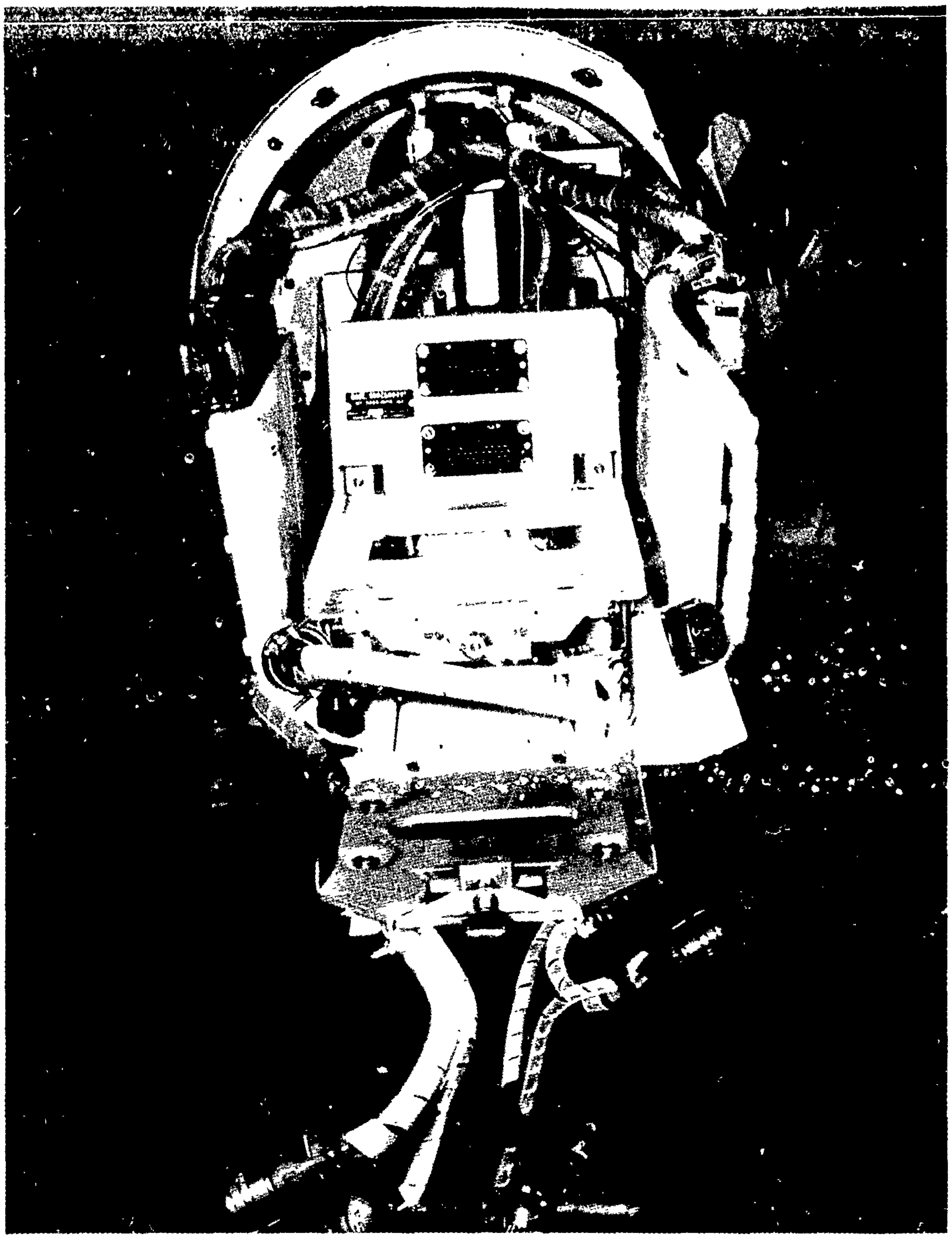


Figure 3-43. Pod 2 Aft Beam and Aft End of Center Section Wiring (View Aft Center).

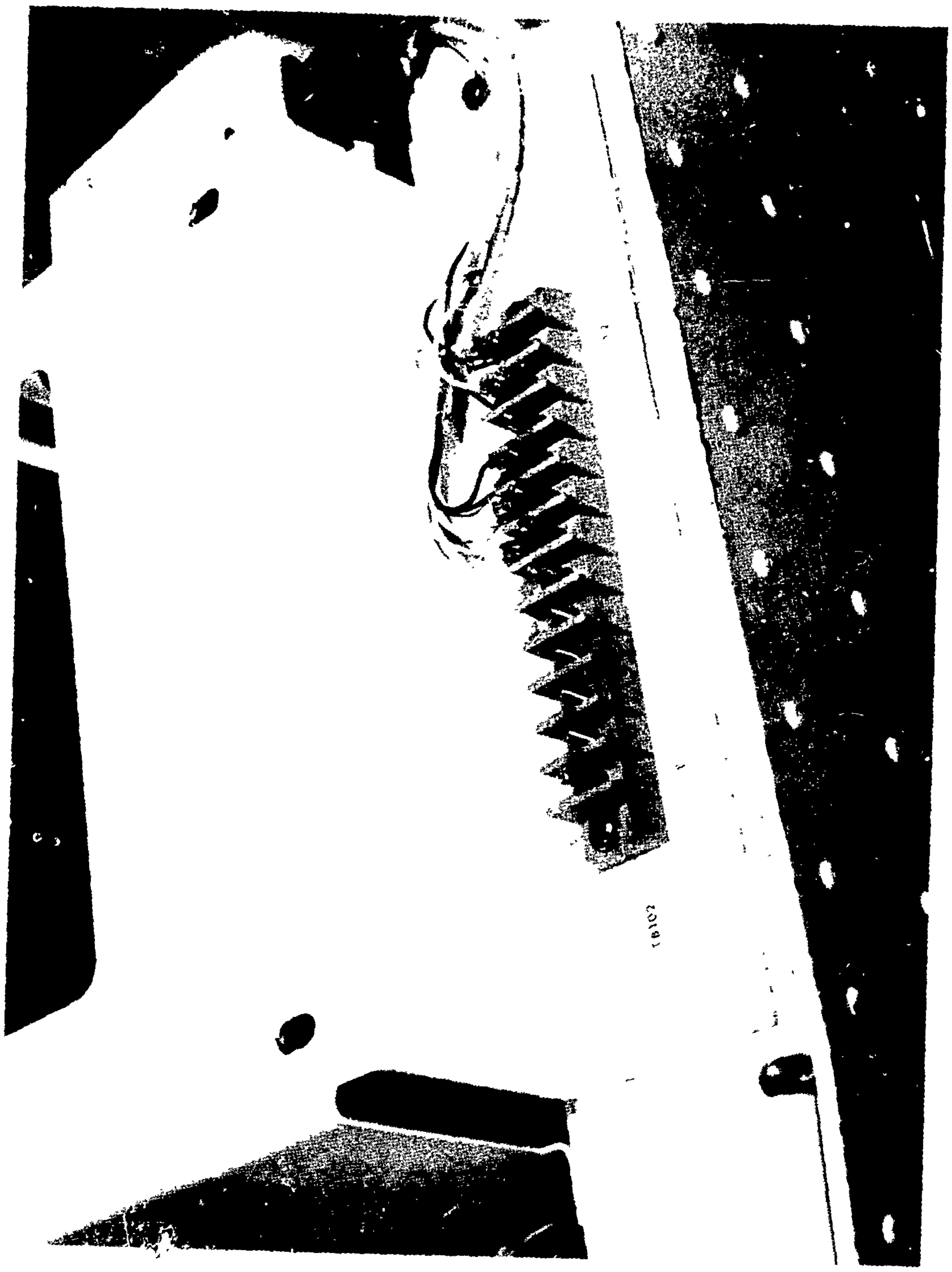


Figure 3-44. Pod 1 Aft Beam Wiring (View Forward End Right Bottom).

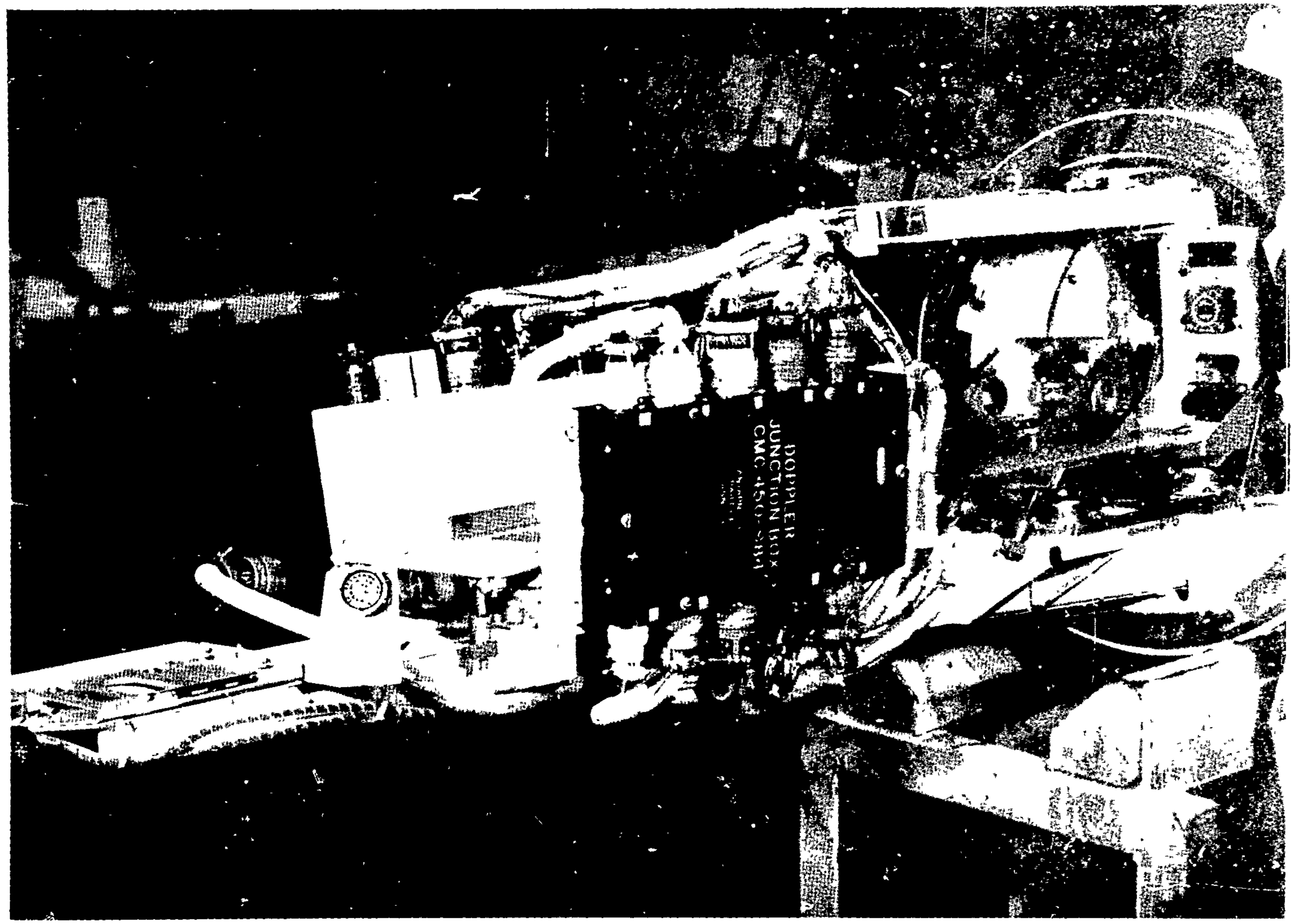


Figure 3-45. Pod 2 Aft Beam and Aft End of Center Section Wiring (View Right Aft).

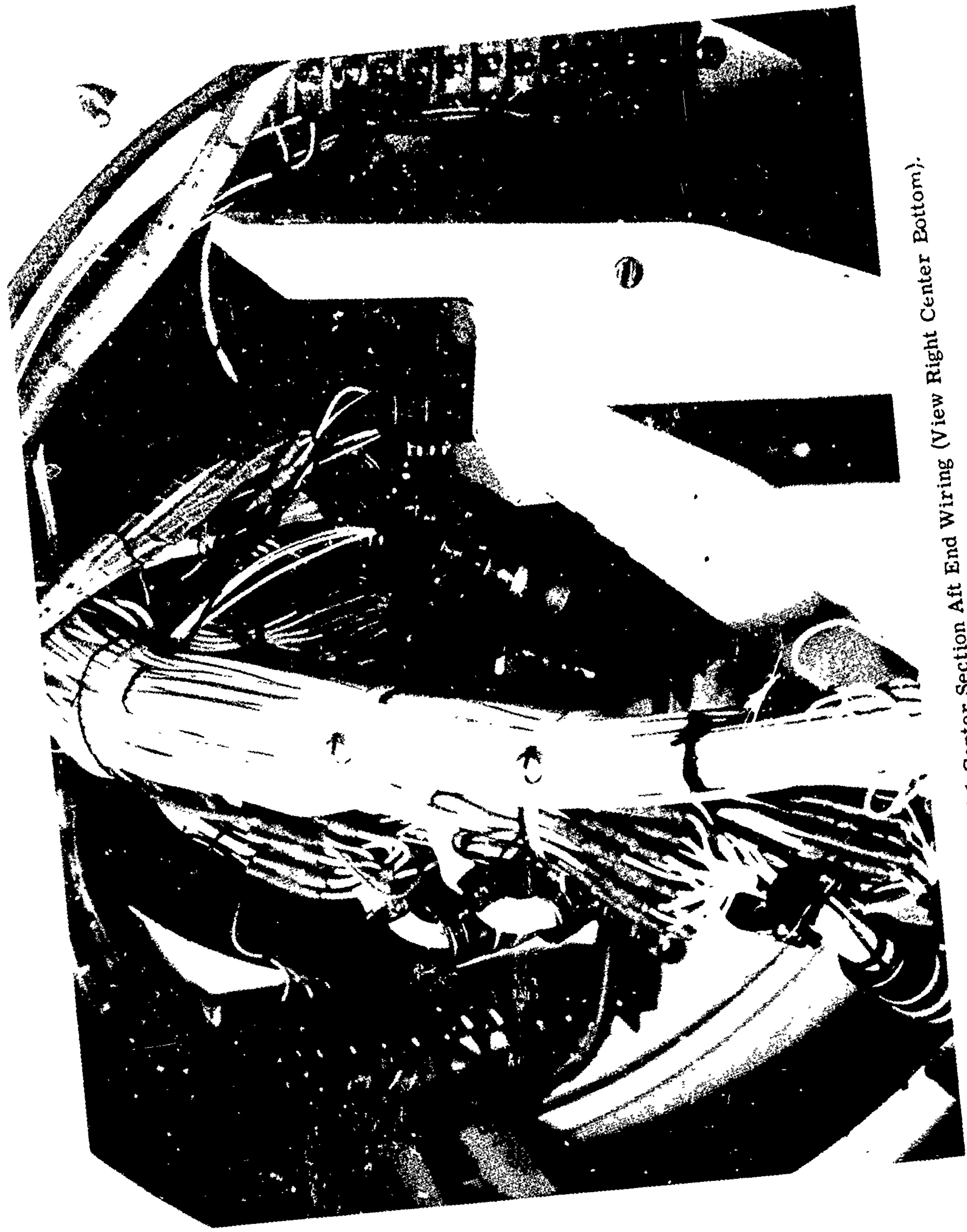


Figure 3-46. Pod 1 Center Section Aft End Wiring (View Right Center Bottom).

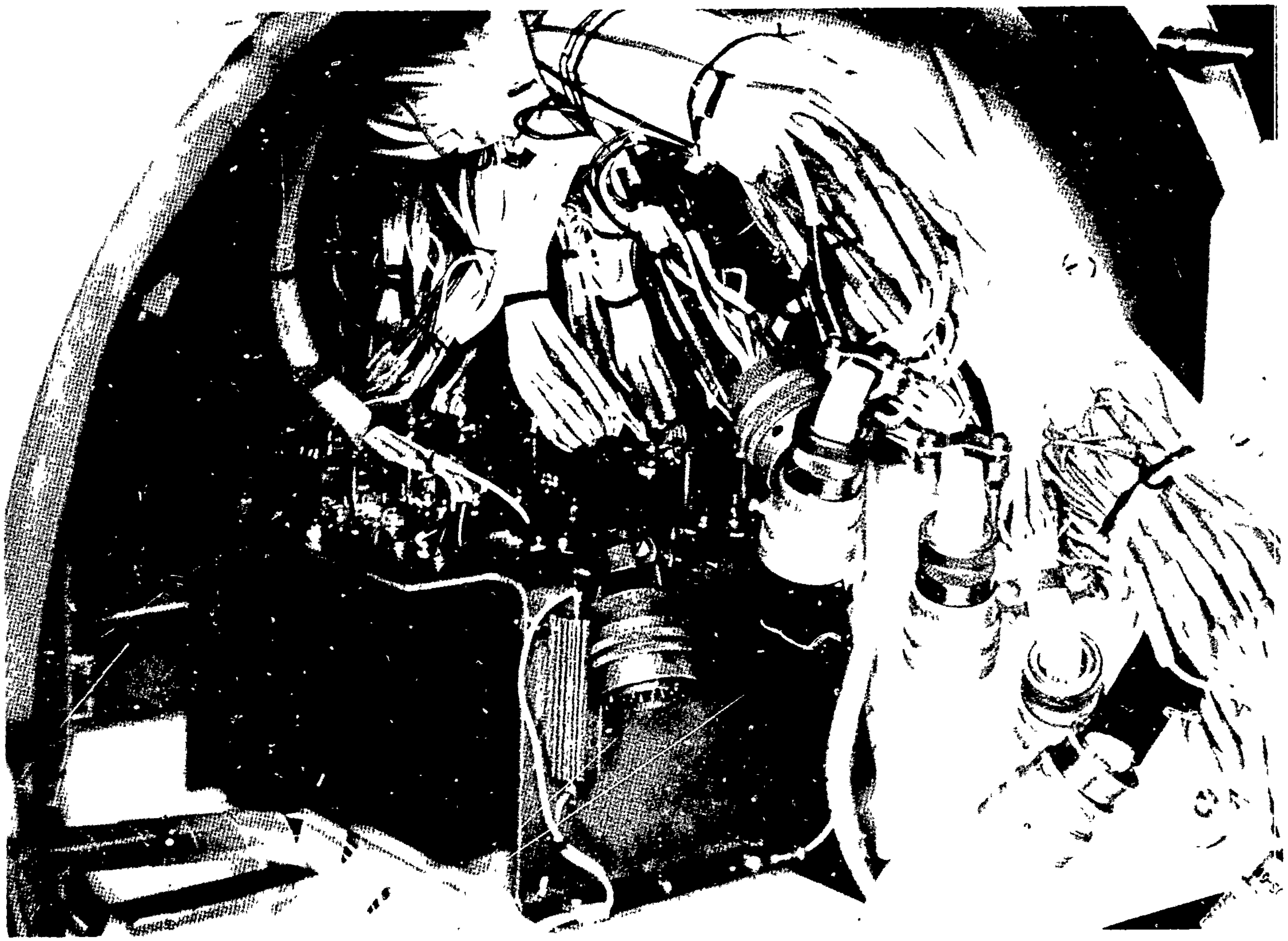


Figure 3-47. Pod 1 Center Section Aft End Wiring (View Left Center Bottom).

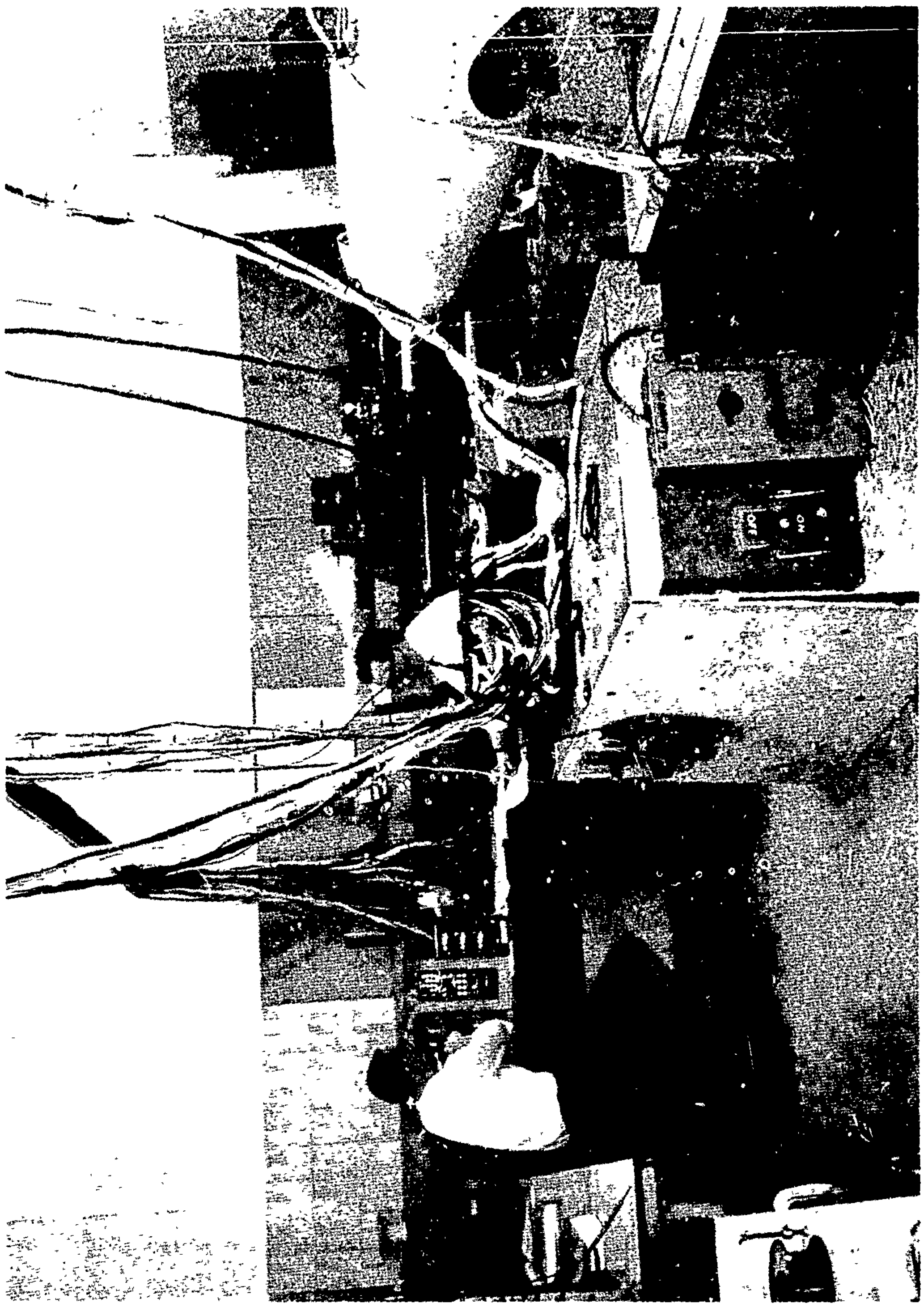


Figure 3-48. Laboratory Facilities—Pod 2 and Cockpit Equipment Checkout.

Figure 3-49. Navigation Set—Testing Facilities.

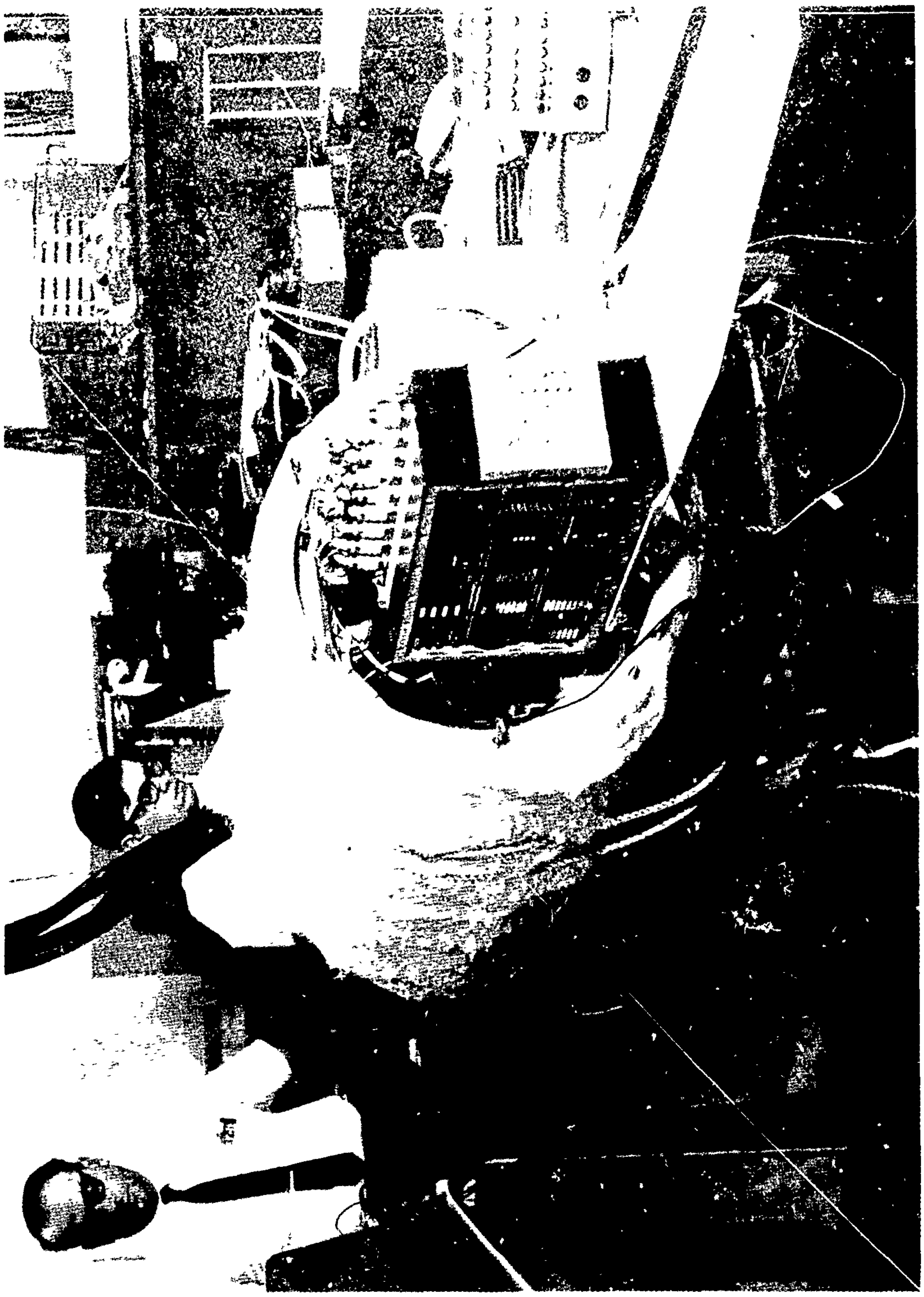


Figure 3-50. Pod 1 Equipment Checkout.

3.5.1.1 System Test Specification—Section II. This section of the system test specification was performed, and provides a laboratory sequence for extensively checking subsystem operation and interface within the AMPD-224 system. The checkout does not check each individual system unit, but provides checks extensive enough to underline any subsystem faults down to the unit level.

The checkout was stopped whenever any problems were found, and the problems were corrected. Completion of this checkout indicated that the individual subsystems were operating properly, and that signal conversion accuracy was within the desired specifications on all signals.

The time-of-day clock and the meteorological subsystems were not checked. The TOD clock was not operating properly during this checkout, but it was repaired and checked at a later date. The meteorological subsystem was not available for checkout at this time. It was received and checked at a later date, and was found to operate properly.

3.5.1.2 Additional System Tests. Additional system tests were performed on the system as follows:

Temperature tests were run on each pod to determine possible heat problems and find the most suitable location for temperature warning thermostats. The tests indicated that a potential temperature problem existed in the aft section of Pod 2. However, it was decided that the flow of air during flight would eliminate any tactical temperature problem, and running the pod on the ground presented no problem if the hand hold covers were left open or the aft pod cover was moved back a few inches. No temperature problems were found in Pod 1.

The accuracy of the present position synchros was checked. This revealed that backlash in the control indicator present position gearing made the present position readout on the control indicator inaccurate. The inaccuracy was minimized by adjusting the idler gear in the present position gear train until the average error was zero. This checkout and the resulting calibration procedure is shown in Appendix A.

The accuracy of the TMG synchro was checked and found to be ±2 degrees and evenly distributed about zero error. This error is in the TMG synchro itself, and cannot be reduced.

The G/S synchro accuracy was checked and found to be well within system accuracy requirements. However, backlash error was found in the gearing between the G/S synchro repeater and the VSI G/S visual readout. As a result, the VSI readout of G/S is accurate to (at best) ±2Kts.

System noise was checked, and it was found that all analog signal lines required filtering. A filter (RC 10K and 0.1 μf) was inserted at the input to the A/D converter for all analog lines. This filter eliminated noise effects on A/D conversion accuracy. The S/D converter was found to generate considerable noise back onto the synchro input lines. The line to line capacitors (0.1 μf) on the synchro inputs were changed to a line to ground configuration, and 10K resistors were put in series with each synchro line at the S/D input. This change eliminated the noise problems on synchro lines.

3.5.1.3 System Test Specification—Section III. This checkout was performed; it provides a number of laboratory test problems which simulate source prediction conditions. Each problem checks a specific math model and flight plan, and exercises the actual source prediction capability of the entire AMPD-224 System. The problem results indicated proper system operation in the following areas.

1. Offset direction and magnitude.

2. Second plume conditions 0.3 and 0.5.

3. Detector vs simulation response.

4. Transition and iteration regions of the math model.

5. Math Models 1, 2, and 3.

6. Multiple plumes.

3.6 INSTALLATION IN AIRCRAFT

The Phase IV systems were installed on both the JOV-1B (Grumman Mohawk) and the UH-1D (Bell Iroquois Helicopter). The first of the systems was installed on a JOV-1B (Tail No. 59-2627) at Westover AFB during February 1968. First flight of the system was on February 24. The second system was installed on a UH-1D, also at Westover AFB, early in March 1968. First flight of this system was on March 8.

The Mohawk installation was by far the more difficult and elaborate of the two. This was partly because the Mohawk was considered to be the primary aircraft for the system and partly because of the complexity of the aircraft itself. The required modifications were performed by Grumman Aircraft Engineering Corp. at Bethpage, L. I. under a separate contract from LWL. Definition of the modifications was a joint effort of GAEC and GEOS. The effort began with informal contacts starting in March, 1967, and continued under contract through the first flight of the system. During this period, information was interchanged in meetings, letters and telephone conversations. Documentation of the mutually-agreed-upon requirements is contained in SK-AMPD-13 (see table 3-17) "Installation of the Aircraft Mounted Personnel Detector in the JOV-1B Aircraft." This specification spells out system requirements and describes the appropriate work interfaces.

On the Mohawk, the pods are mounted on the stores pylon at Station 185 on each wing. The major aircraft modification involved routing through the wings the hundreds of wires which connect the pods to the fuselage-mounted system components and mounting the necessary electrical connectors on the lower surface of the wing.

A second major modification was needed to provide mounting for the system cockpit display panels. This required removal of some standard equipment and design and construction of a tray to mount display panels in locations that suited the convenience of the observer.

As delivered to Westover, the aircraft was ready to have system components plugged in. From this point on, system installation and checkout was performed by GEOS personnel. After some preliminary flight tests, the aircraft returned to Grumman for compass swing and electro-magnetic interference checks. The aircraft then flew to Florida for field testing. See figures 3-48 through 3-52 showing system units installed in the aircraft.

Mounting the system on the helicopter was much simpler than mounting it on the OV-1. All aircraft modification and system installation was done by GEOS. A visit by GEOS personnel to Bell Helicopter Co. in February, 1967 provided initial information. Detailed information required at a later time was obtained by examination of the helicopter.

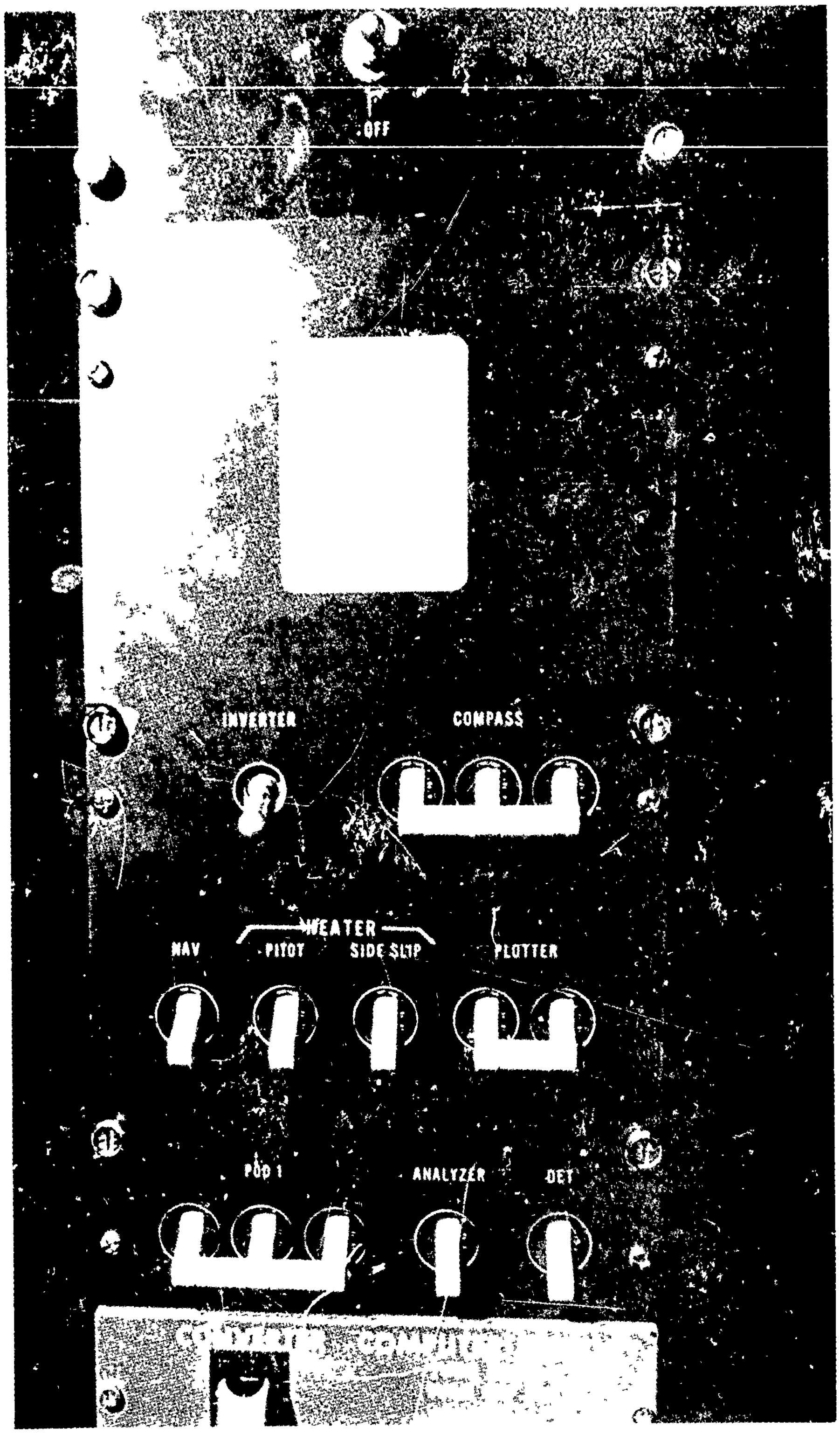


Figure 3-51. Power Panel.

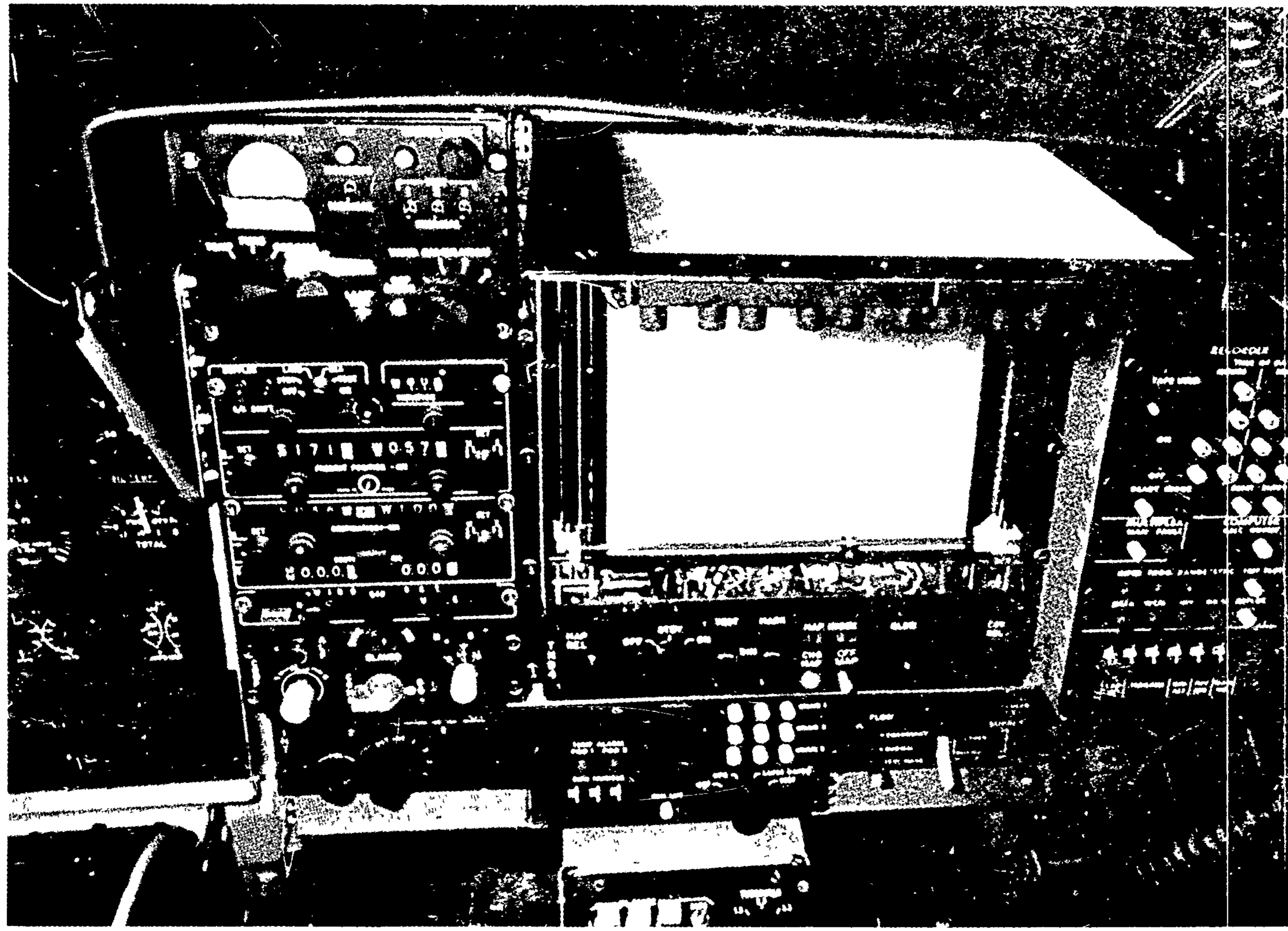


Figure 3-52. AMPD System Cockpit Display.

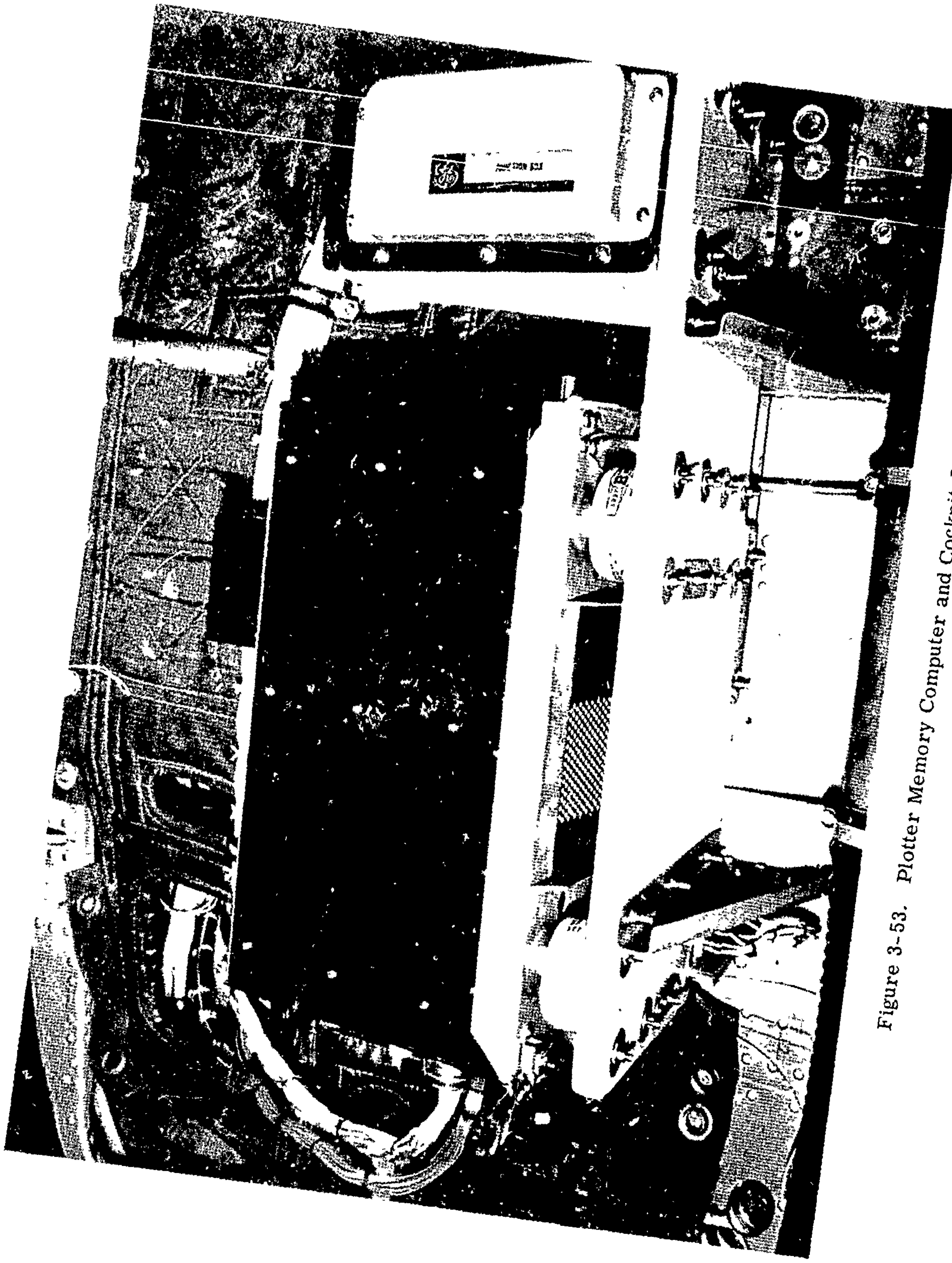


Figure 3-53. Plotter Memory Computer and Cockpit Junction Box.

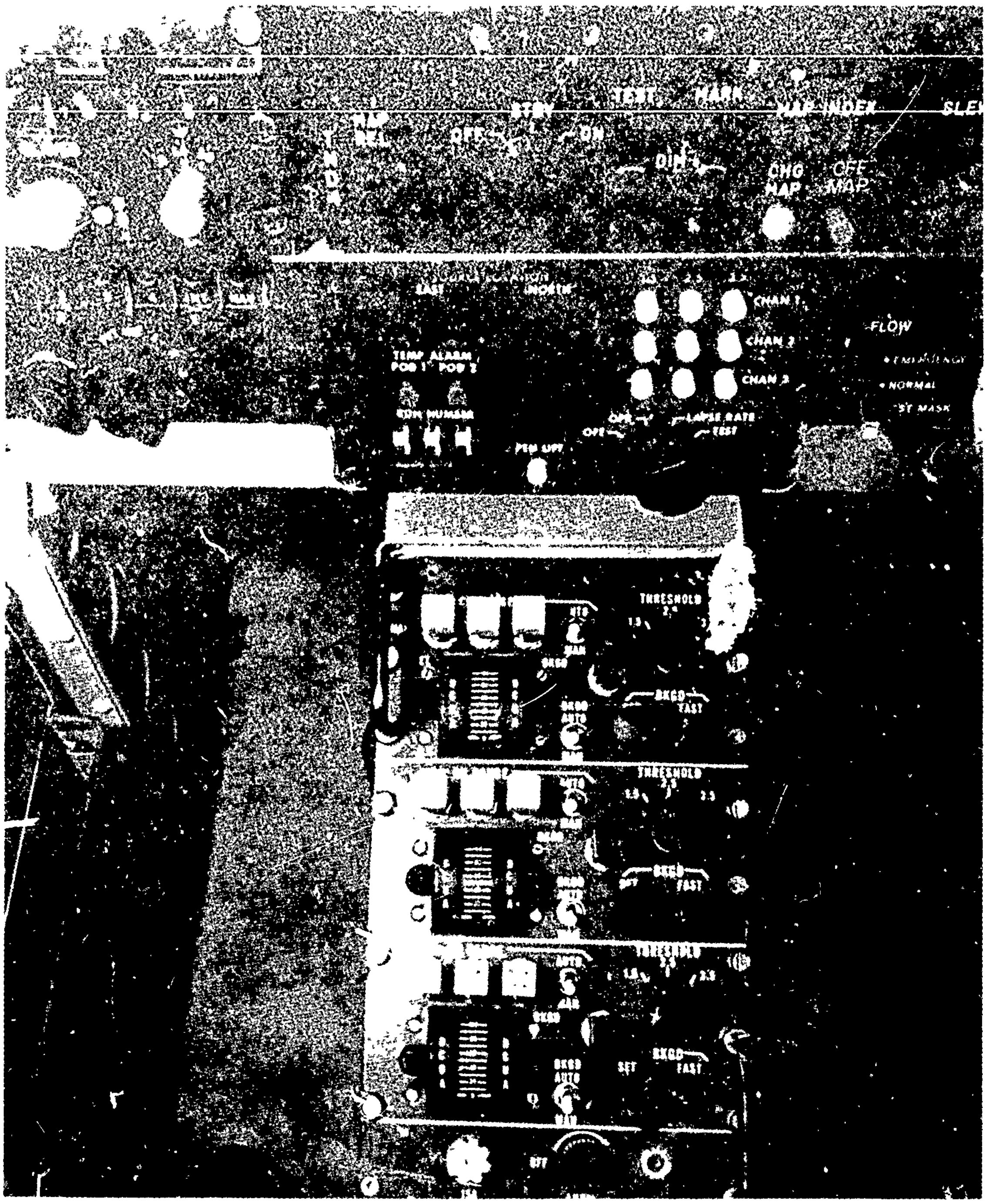


Figure 3-54. Analyzer.

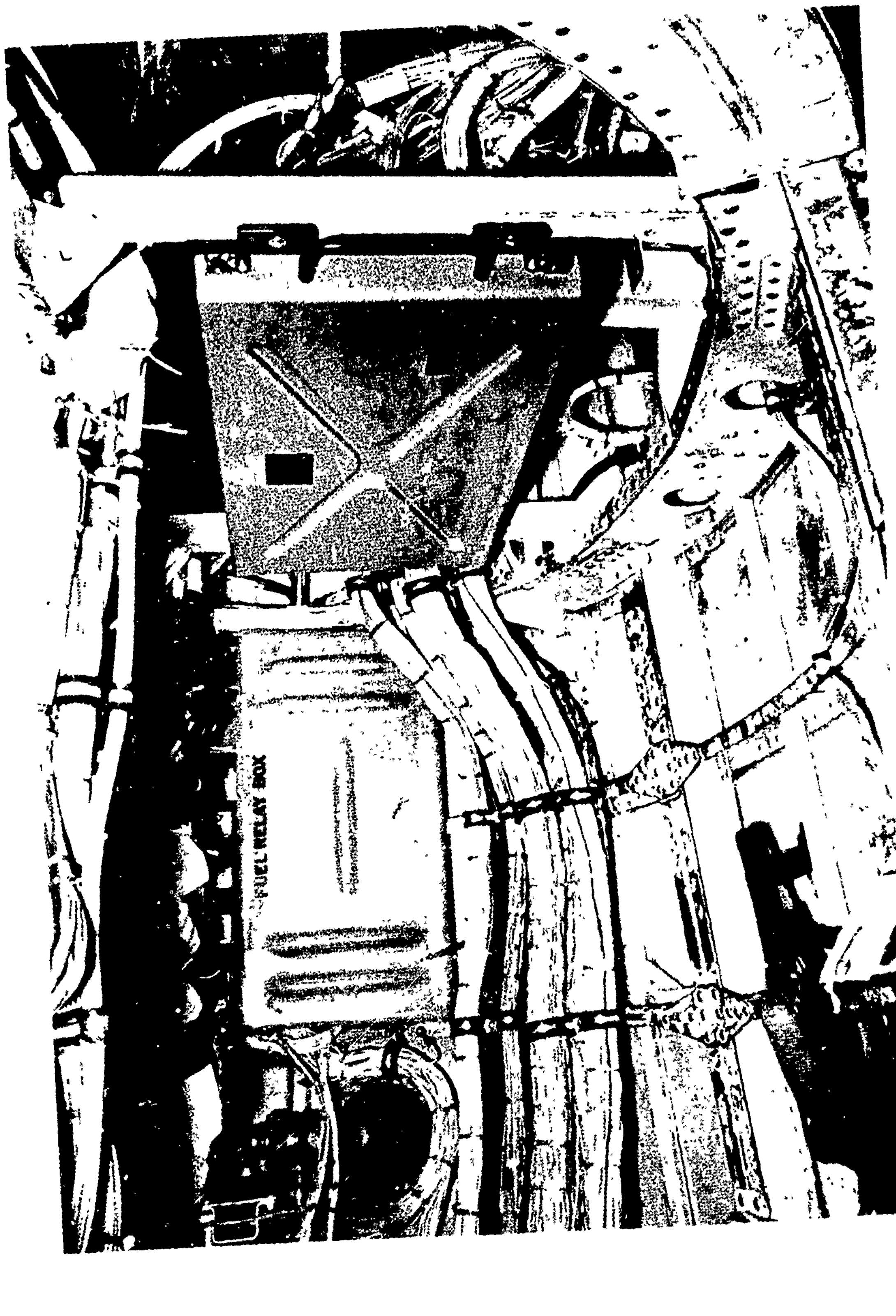


Figure 3-55. 0V-1 Baggage Compartment.

The helicopter had plenty of room to accomodate display panels and junction boxes in a specially constructed console which latched to the fuselage floor. It was a simple matter to route cables from the console through the ammo chutes and out to the pods. A standard helicopter stores rack was slightly modified to carry the pods. Details of the installation are spelled out in SK-AMPD-14, "Installation of the Aircraft Mounted Personnel Detector in the UH-1D Helicopter."

After the system was installed, the helicopter was test flown successfully. It then departed for the Florida test site via Ft. Rucker, Alabama. At Fort Rucker, compass swing was performed. The helicopter then proceeded to Homstead AFB for further system tests.

At the end of May, 1968, the system was removed from the helicopter at Aberdeen and installed on the second 0V-1 (Tail No. 59-2633). The system was first flown on 1 Jul 68.

During the earlier stages of the program, some fairly elaborate equipment had been considered for handling the pods during installation on the airplane. However, as the system evolved, it became obvious that no special equipment was needed. The pods could be stripped down in weight to the point where manhandling them became entirely feasible. This was confirmed by experience with the Phase II system. Therefore, the only major items of ground support equipment supplied for handling the pods during installation was a pair of low-boy dollies for transporting the pods over short distances.

3.7 SYSTEM CHECKOUT IN AIRCRAFT/WESTOVER AFB

System/Aircraft checkout was performed at Westover AFB from 14 Feb 68 to 7 Mar 68. System 1 was checked out in the J0V1-B (27) aircraft from 14 Feb 68 to 27 Feb 68 and System 2 was checked out on the UH-1D (89) aircraft from 5 Mar 68 to 7 Mar 68. A summary of these checkouts by dates follows.

3.7.1 System Checkout at Westover AFB—J0V1-B (27) Mohawk Aircraft.

1. System checkout began 2 Feb 68. The pylon connectors were checked to ensure that the connector pins were correctly aligned. Both pylon connectors were found to be correctly aligned.

   Prior to applying power to the 224 AMPD system, the power distribution throughout the system was checked. This was accomplished by removing all system equipment, and checking the voltages at the appropriate equipment connectors. This checkout indicated that the wiring was correct.

2. A check of the analyzer 15 Feb 68 revealed that the automatic range switch shut-off circuit was not functioning properly in two analyzer channels. An investigation of the problem was started.

3. Installation of cockpit equipment (16 Feb 68) revealed that the mounting assembly did not have the correct dimensions, and required some rework before the test panels, plotter and analyzer could be properly installed. The analyzer range switch shut-off problem was due to some faulty RSD modules. These modules were replaced.

   Power was applied to Pod 2, and a quick checkout indicated that all Pod 2 equipment was functioning normally. Power was applied to Pod 1, and a problem was found in the circuit breaker. Connecting the Mk 12 computer or the MPXR maintenance panel caused the Pod 1 circuit breaker to trip. It was suspected that the DRO power

power supply might be the cause. The DRO was removed, bench-tested, and found to function normally. Other circuit breakers were also found to trip for no apparent reason. The power panel was investigated.

4. On 19 Feb 68, the power panel was found to be incorrectly wired. Some circuit breakers were in the wrong location due to incorrect identification numbers being stamped on the power panel. The power panel was removed and rewired. The +6v Abbott Power Supply was found to be defective. It was removed and replaced.

5. The plotter off-map indication (21 Feb 68) did not function properly. In all other respects, the plotter functioned normally. The navigation subsystem functioned normally. The MRI temperature probe was found to have a defective sensing element. The temperature probe was replaced, and the MRI was found to function normally.

   The accuracy of the VSI representation of wind was checked by setting in a wind on the VSI and recording the digital readout of the wind potentiometer voltage. The acceptable readability on the VSI is ±2Kts; the data follows in table 3-13.

6. Program tapes could not be read (19 Feb 68) into the Mk 12 computer. The S/N 66160 CPU was found to be defective. Temporarily, the CPU located on the C47 (ϕ2) aircraft was used to replace the defective CPU. A tape was loaded, and a quick check of Pod 1 equipment indicated that the WCM lamp was always set; the analog wind was OK; switch setting was OK; test plot functioned properly, and offsets were being drawn in the correct direction.

7. The WCM problem was found (20 Feb 68) to be due to a short circuit between the system mode switch and the WCM lamp on the cockpit junction box.

   MRI equipment was installed on the system.

   Program tape (16 Feb 68) was read in to check out all the inputs. All inputs checked out properly. The input and output of the set command level converter was checked. Noise is not a problem at the output and the level converter appears to have enough noise rejection. The recorder could not be set to the ready mode from the cockpit. A wiring error was found in the system junction box and corrected. The recorder interface checked out correctly.

   The circuit breakers were found to arc. This was brought to the attention of the aircraft pilot and no problem was forseen. The circuit breakers were not military circuit breakers.

   Section II of the system test specification was begun.

8. Section II of the system test specification was completed (21 Feb 68); the results follow. Accuracy of both the A/D and S/D converters was within specifications. Digital subsystem worked properly. Chemical subsystem functioned properly.

9. The calibration of the control indicator (SN #336) present position readout was checked (21 Feb 68). The checkout indicated that the E/W calibration had slipped since its last adjustment. The control indicator was replaced with a spare unit recently calibrated. The present position data for control indicator SN 336 is plotted in figure 3-56.

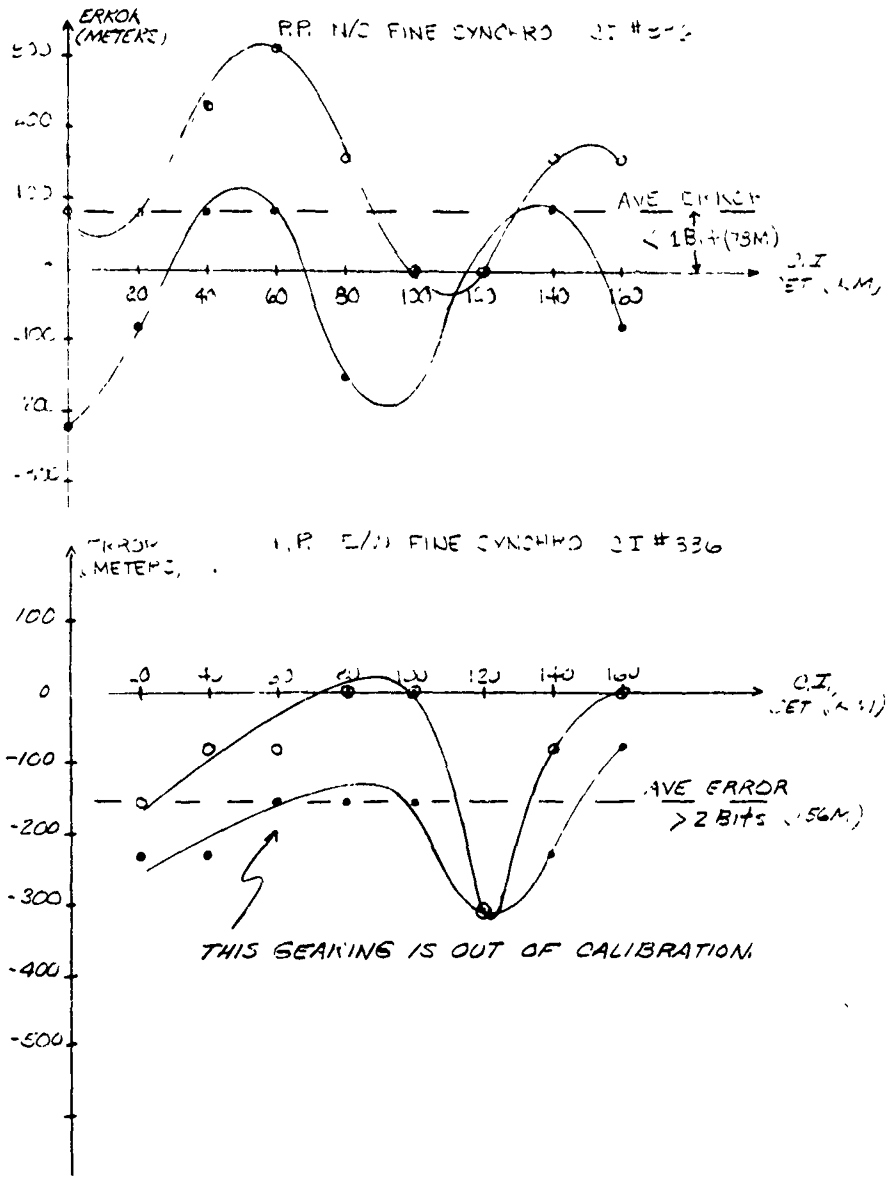
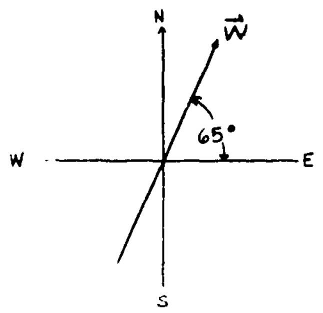


Figure 3-56. Control Indicator 336 Calibration Check of Present Position Readout.

S/S = 150 KNOTS
TMG = 90°
TAS = 142.2 KNOTS
DRIFT ANGLE = 6° (LEFT)
WIND = 21.82 KNOTS
ΘW = 65°
MATH MODEL 1
TURBULENCE = D
ORIGIN = 4KM $\vec{N}$, 1KM $\vec{E}$
DESTINATION = 4KM $\vec{N}$, 9KM $\vec{E}$
MAP SCALE = 10KM X 10KM
THRESHOLD = 2.5
SOURCE = SIMULATED CH 1
CALCULATION = ITERATION

Westover Checkout
2/19/68 → 2/27/68



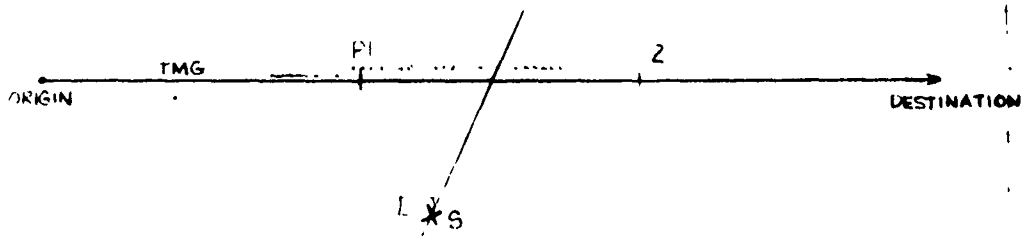


Figure 3-57. Problem 3/1.

TABLE 3-13. VSI DIGITAL READOUT DATA

VSI Set	Digital Readout	Equivalent
Wind Potentiometer E/W		
0Kts E	2^5	0 Kts E
10Kts E	$2^5 2^2 2^1$	9.37Kts E
20Kts E	$2^5 2^3 2^2$	18.75Kts E
30Kts E	$2^5 2^4 2^1 2^0$	29.68Kts E
40Kts E	$2^5 2^4 2^3 2^1$	40.62Kts E
50Kts E	all Bits	50 Kts E
10Kts W	$2^4 2^3 2^1$	9.38Kts W
20Kts W	$2^4 2^1 2^0$	20.32Kts W
30Kts W	$2^3 2^2 2^0$	29.69Kts W
40Kts W	$2^3 2^1$	40.63Kts W
50Kts W	0 Bits	50 Kts W
Wind Potentiometer N/S		
50Kts N	all Bits	50 Kts N
40Kts N	$2^5 2^4 2^3$	37.5 Kts N
30Kts N	$2^5 2^4 2^1$	28.12Kts N
20Kts N	$2^5 2^3 2^2$	18.75Kts N
10Kts N	$2^5 2^2 2^1$	9.37Kts N
0Kts N	2^5	0 Kts N
10Kts S	$2^4 2^3 2^0$	10.94Kts S
20Kts S	$2^4 2^2 2^0$	17.18Kts S
30Kts S	$2^3 2^2 2^0$	29.69Kts S
40Kts S	$2^2 2^1$	40.64Kts S
50Kts S	0 Bits	50 Kts S

10. The analog signal lines were checked (23 Feb 68) for noise. The resulting data follows:

Noise measured at the aircraft junction box:

Digital Ground	AJ4-02	0.2VPP at 400 Hz
Temperature	AJ4-13	0.2VPP at 400 Hz
Turbulence	AJ4-14	0.2VPP at 400 Hz
A/C 28vdc	CJ2-05	2.0VPP at 400 Hz
*CH 1 Background	BJ3-26	0.5VPP at 160 kHz
*CH 2 Background	BJ3-27	0.5VPP at 160 kHz
*CH 3 Background	BJ3-28	0.5VPP at 160 kHz
*CH 1 Detector	AJ5-01	0.5VPP at 160 kHz
*CH 2 Detector	Not available	
*CH 3 Detector	Not available	
Wind E/W	BJ3-30	0.2VPP at 400 Hz
Wind N/S	Not checked	
Altitude	BJ3-29	0.6VPP at 160 kHz
		0.2VPP at 400 Hz

*Measured with respect to instrument ground.

11. The Meteorological meter on the system test panel was modified (26 Feb 68) to indicate the angle of the side slip sensor when position side slip is selected. One simulated test problem was run. The problem (figure 3-57) produced a correct plot in both magnitude and direction.

12. JOV1-B Mohawk Aircraft left 27 Feb 68 for Grumman Aircraft Engineering Corp in Bethpage, L.I., for a compass swing and RFI checkout.

3.7.2 System Checkout—UH1-D (89) Aircraft

1. System installation on helicopter was started 5 Mar 68. The console was put in place, pods were then mounted on modified antler assembly. Pylon connectors were mounted on antlers and cables installed (excess cable was coiled in the bottom of the console). The console was locked down and all units, system junction box, and cables installed.

2. Began continuity checks (6 Mar 68) of all cables. Several pins were bound in the pylon connectors pushed out of place. Pieces of metal in sockets prevent positive locking of some pins.

   Wire-checked pylon power cable for Pod 1 and Pod 2. Buss bar was found missing in the type 2 junction box connector CP4, which was causing system ground to Pod 1 to be missing. The following pins were affected: CP4 pins 13, 14, 15, 16, 18 and 19. A buss bar was added between CP4 pins 16 and 26 to correct same. Power was then applied to both pods, and the equipment was checked out. This fix seemed to have eliminated the following:

   a. Intermittent out-of-sync while system test was in progress.

   b. Resetting of time-of-day clock while lamp test pushbutton was depressed.

Found the two's of hours not working in the entry mode. A pin in the pylon connector was pushed back; did not repair same for lack of time to check out rest of system.

3. Continued system test (7 Mar 68) and made a test flight at 1300 hours. Flux check errors occurred while in flight. Unable to determine cause. (Suggest: Vibrate spare recorder at OP 2 with power applied in order to determine cause of failure.) Digital readout of synchros sometimes were noisy. No reason was found for this intermittent problem. Compass rotation and heading were wrong. J0V1 wiring was checked to determine proper wiring.

The helicopter left for compass swing at Fort Rucker, Alabama.

3.8 RFI CHECKOUT AT GAEC–28 Feb 68 to 3 Mar 68

The possibility of interference between the operation of the AMPD-224 system and normal aircraft navigation and communication equipment was investigated. The tests were conducted at Piconic, Long Island by E. Behnke/GAEC and K. Sheehan/GEOS.

The following J0V1-B aircraft navigation and communication equipment was investigated:

1.	Automatic range finder	ARN-59
2.	R/T VHF set 30-69.95 MHz	ARC-54
3.	Marker beacon	ARN-58
4.	Instrument landing Sup. Receiver	ARN-30
5.	R/T UHF Set 225-399.9 MHz	ARC-51
6.	Glide slope receiver	ARN-58
7.	R/T identification (Friend or Foe)	APX-44
8.	R/T VHF 119-149 MHz	ARC-134

The checkout was performed in the following manner: All the indicated aircraft equipment was turned on, and the effects (if any) on their normal operation due to selected modes of the AMPD-224 system operation were noted. This data is listed in tables 3-14 and 3-15.

The AMPD-224 system was turned on and the effects (if any) on its normal operation due to operation of aircraft equipment operation were noted. The resulting data is listed in table 3-16. No RFI problems were encountered between the AMPD-224 system and the aircraft navigation and the communication equipment.

3.9 COMPASS SWING

3.9.1 UH-1D (89) Aircraft—System 2

The helicopter arrived at Ft. Rucker, Ala. on 11 Mar 68 for compass swing. The compass swing was accomplished as follows:

1. The first action (11 Mar 68) at Fort Rucker was to correct the compass transmitter wiring. A rough check of the compass system was then made on the compass rose.

TABLE 3-14. AMPD-224 EFFECT ON AIRCRAFT GEAR (ANALYZER SOURCE)

(Source) Analyzer (CH. 1, 2, 3)	ARN-59	ARC-102	ARC-54	(Affect on Equipment) ARN-58	ARN-30	ARC-51	ARN-58	ARC-134	APX-44
Range Manual	OK	This	OK	OK	OK	OK	OK	OK	Not possible
Range Auto	OK	Gear	OK	OK	OK	OK	OK	OK	to check.
B'gnd Integ Auto	OK	Not	OK	OK	OK	OK	OK	OK	
B'gnd Integ Auto	OK	In	OK	OK	OK	OK	OK	OK	
Audio Alarm Signal	OK	A/C	OK	OK	OK	OK	OK	CK	
*Detector ($CH+NH_3$)	OK		OK	OK	OK	OK	OK	OK	
**Corona Converter at 18μa (with shunt)	OK		OK	OK	OK	OK	OK	OK	
Pump Current Surge	OK		OK	OK	OK	OK	OK	OK	
Doppler Navigator									
1 Stby	OK		OK	OK	OK	OK	OK	OK	
Land	1		1	1	1	1	1	1	
Sea	OK		OK	OK	OK	OK	OK	OK	
Test	1		1	1	1	1	1	1	
Air	OK		OK	OK	OK	OK	OK	OK	
PP E/W Slew	OK		OK	OK	OK	OK	OK	OK	
PP N/S Slew	OK		OK	OK	OK	OK	OK	OK	
Destroy 1 Slew	OK		OK	OK	OK	OK	OK	OK	
Destroy 2 Slew	OK		OK	OK	OK	OK	OK	OK	

Table 3-14. AMPD-224 Effect on Aircraft Gear (Analyzer Source) (Continued)

(Source) Analyzer (CH. 1, 2, 3)	ARN-59	ARC-102	ARC-54	(Affect on Equipment) ARN-58	ARN-30	ARC-51	ARN-58	ARC-134	APX-44
Gyro (GE)									
Fast Erect	OK		OK	OK	OK	OK	OK	OK	
Slew	OK		OK	OK	OK	OK	OK	OK	
Pod 1 Gear									
Test Mode	OK		OK	OK	OK	OK	OK	OK	
Oper Mode	OK		OK	OK	OK	OK	OK	OK	
Test Plot	OK		OK	OK	OK	OK	OK	OK	
Replot	OK		OK	OK	OK	OK	OK	OK	

[1]Switching between these positions causes a change in the level of ICS B'gnd noise, because of loading/unloading of 28v power.

**Requires filter and Tyson tubing/Converter
*Are detectors operable

TABLE 3-15. AMPD-224 EFFECT ON AIRCRAFT GEAR (RECORDER SOURCE)

(Source) Recorder	ARN-59	ARC-102	ARC-54	(Affected Equipment) ARN-58	ARN-30	ARC-51	ARN-58	ARC-134	APX-44
*Ready/ON removed from system. 1 Mar 68		This gear not in air-craft							
Plotter TND-4									
Test	OK		OK	OK	OK	OK	OK	OK	OK
Slew E/W	OK		OK	OK	OK	OK	OK	OK	OK

Table 3-15. AMPD-224 Effect on Aircraft Gear (Recorder Source) (Continued)

(Source) Recorder	ARN-59	ARC-102	ARC-54	(Affected Equipment) ARN-58	ARN-30	ARC-51	ARN-58	ARC-134	APX-44
Slew N/S	OK		OK	OK	OK	OK	OK	OK	OK
Pen Lift	OK		OK	OK	OK	OK	OK	OK	OK
Mark	OK		OK	OK	OK	OK	OK	OK	OK
Cockpit Panels									
TODC	OK		OK	OK	OK	OK	OK	OK	OK
Reset	OK		OK	OK	OK	OK	OK	OK	OK
Update	OK		OK	OK	OK	OK	OK	OK	OK
Lamp Test	2								
Additions:									
Press to store	OK		OK	OK	OK	OK	OK	OK	OK
Wind slew (stbt)	OK		OK	OK	OK	OK	OK	OK	OK
All det's on with Filter Box (5K, no conv)	OK		OK	OK	OK	OK	OK	OK	OK
Discretes	OK		OK	OK	OK	OK	OK	OK	OK

[2] A click is heard on ICS during lamp test.

*Can recorder be run without a cartridge.

TABLE 3-16. AIRCRAFT TRANSMITTING GEAR EFFECT ON AMPD-224 GEAR

APX-44 (IFF)	ARN-52 (Tacan)	ARC-51	ARC-134	ARC-54 (VHF T/R)	ARC-102 (HF T/R)	(Source) (Affected Gear)
OK	This gear	OK	OK	OK	This gear	Wind E/W A/D Input
OK	not in	OK	OK	OK	not in	Wind N/S A/D Input
OK	Aircraft	OK	OK	OK	Aircraft	CH 1 B'gnd A/D Input
OK		OK	OK	OK		CH 2 B'gnd A/D Input
OK		OK	OK	OK		CH 3 B'gnd A/D Input
OK		[1]OK	[1]OK	[1]OK		CH 1 Detector A/D Input
OK		[1]OK	[1]OK	[1]OK		CH 2 Detector A/D Input
OK		OK	OK	OK		CH 3 Detector A/D Input
OK		OK	OK	OK		Altitude A/D Input
OK		OK	OK	OK		Temperature A/D Input
OK		OK	OK	OK		Turbulence A/D Input
OK		OK	OK	OK		Computer Memory
OK		OK	OK	OK		G/S S/D Input
OK		OK	OK	OK		TMG S/D Input
OK		OK	OK	OK		PP Fine E/W S/D Input
OK		OK	OK	OK		PP Fine N/S S/D Input
OK		OK	OK	OK		PP Course E/W S/D Input
OK		OK	OK	OK		PP Course N/S S/D Input
OK		OK	OK	OK		Multiplexer Error
OK		OK	OK	OK		[3] False Analyzer Alarms
OK		OK	OK	OK		[3] False Plotter Mark
OK		OK	OK	OK		[3] Plotter Track Error
OK		OK	OK	OK		Recorder Error

[1]In test mode, there is a 1-bit fluctuation when keying transmitter, because APS 28v drops when transmitter is keyed, analyzer range changed, or navigator turned on.

[2]When FM transmitter is keyed, there is a 1-bit variation in the turbulence digital readout.

[3]Air mode track.

When the compass system seemed to be operating properly, the MC-2 test set was set up and a magnetic survey was made using a standard flux valve. The flux valve was then mounted in the test stand and compensated, using its adjustments.

2. The helicopter was set down (12 Mar 68) on a surveyed line and the compass transmitter was remounted on the Pod. The transmitter was then optically aligned to the pod by using plumb bobs to determine the pod position. A telescope was used to align the transmitter. The transmitter was then locked in place. The helicopter was then started and run at its normal speed, while 24-point compensation of the electronic unit of the compass system was accomplished. It was apparent that the transmitter swings ±2 degrees because of vibration and/or electrical interference. The gyro is able to integrate the transmitters signal and correctly indicate magnetic heading to within ±0.4 degree for all headings during calibration.

3.9.2 JOV1-B (27) Aircraft—System 1

The Mohawk aircraft arrived at GAEC, Bethpage, L.I. (2 Feb 68) for compass swing and RFI testing. The compass swing was performed during the week of 3 Mar 68 with the entire AMPD-224 system operating. After completing the compass swing, accuracy checks were made at every 15 degrees (starting from 0 degree). The largest error that was observed was 2 minutes. This error was well within the flux valve specification accuracy requirements of ten minutes.

GAEC pointed out possible AMPD-224 system conditions which they felt could cause some compass subsystem inaccuracies. First of all, pod vibration might manifest itself as noise or cause saturation on the amplifier, thus degrading operation. Secondly, the flux valve was mounted in the aft section of Pod 2; this pod section was periodically removed, thus creating a possible misalignment problem between the flux valve and the doppler antenna. No problems were found in these areas during subsequent flight testing.

3.10 WIND CALIBRATE MODE (WCM)

Wind Calibrate Mode was used for determining and correcting errors in the wind solution of the doppler navigation computer. Need for the Wind Calibrate Mode is explained in para 3.10.1 following.

3.10.1 Determination of Wind Data From Groundspeed Measurement

The AMPD-224 system requires an accurate knowledge of the wind vector as an input to the meteorological model. The wind solution in the doppler navigation computer may not be adequate. In this computer, wind is calculated as the vector difference between groundspeed and true airspeed. The doppler navigator measures the groundspeed vector quite accurately (0.2 percent in velocity and 0.2 degree in heading). However, the true airspeed vector data has errors that are estimated to have an order of magnitude greater error (5 percent velocity and 2 degrees in heading). Therefore, a wind solution based on groundspeed data only should produce a more accurate solution for wind.

The vector relationship between groundspeed ($\underline{Vg}$), true airspeed ($\underline{Va}$), and wind ($\underline{W}$) is shown on figure 3-58. Nomenclature that applies is:

	Nomenclature
$\underline{Vg}$	Groundspeed vector
Vg	Groundspeed magnitude

Nomenclature—Continued

A	Ground track bearing from true north
$\underline{Va}$	True airspeed vector
Va	True airspeed magnitude
D	Drift angle measured from $\underline{Vg}$ to $\underline{Va}$
$\underline{W}$	Wind vector
W	Wind magnitude
B	Wind bearing from true north
$\underline{n}$, $\underline{e}$	North and east unit vectors

In equation form the vector relationship is

$$\underline{Vg} = \underline{Va} + \underline{W} \tag{1}$$

In this equation the groundspeed vector $\underline{Vg}$ is measured by the doppler navigator while the airspeed and wind vectors, $\underline{Va}$ and $\underline{W}$, are unknown. If groundspeed is measured at three different bearings the following set of equations results.

$$\begin{aligned} \underline{Vg1} &= \underline{Va1} + \underline{W} \\ \underline{Vg2} &= \underline{Va2} + \underline{W} \\ \underline{Vg3} &= \underline{Va3} + \underline{W} \end{aligned} \tag{2}$$

Based on the assumption that wind is constant over the measurement period, the wind vector $\underline{W}$ is common to each equation.

Each vector equation for groundspeed yields two linear equations in four unknowns (Va, D, W, B). However, with W and B common to all equations, each new equation introduces two new unknowns (Va and D). Now, if the ratio of true airspeeds can be measured, then each new equation for $\underline{Vg}$ has only one unknown, D, and a set of three vector or six linear equations can be solved for six unknowns.

Let
$$\begin{aligned} Va2 &= K1 \cdot Va1 \\ Va3 &= K2 \cdot Va1 \end{aligned} \tag{3}$$

The expansion of equations (2) into linear form and the substitution of (3) yields:

$$\begin{aligned} Vg1 \cos A1 &= Va1 \cos (A1+D1) + W \cos B \\ Vg1 \sin A1 &= Va1 \sin (A1+D1) + W \sin B \\ Vg2 \cos A2 &= K1 \cdot Va1 \cos (A2+D2) + W \cos B \end{aligned} \tag{4}$$

$$Vg2 \sin A2 = K1 \cdot Va1 \sin (A2+D2) + W \sin B$$

$$Vg3 \cos A3 = K2 \cdot Va1 \cos (A3+D3) + W \cos B$$

$$Vg3 \sin A3 = K2 \cdot Va1 \sin (A3+D3) + W \sin B$$

The division of these equations by Va1 produces terms that are ratios of velocities and are therefore of predictable size. The trigonometric terms that are the sum of A + D can be expanded and small angle approximations made for the drift angle D.

$$\sin D = D$$

$$\cos D = 1 - D^2$$

With these operations, equations (4) become:

$$\frac{Vg1 \cos A1}{Va1} = (1-D1^2) \cos A1 - D1 \sin A1 + \frac{W \cos B}{Va1} \quad (5)$$

$$\frac{Vg1 \sin A1}{Va1} = (1-D1^2) \sin A1 + D1 \cos A1 + \frac{W \sin B}{Va1}$$

$$\frac{Vg2 \cos A2}{Va1} = K1\ (1-D2^2) \cos A2 - K1 \cdot D2 \sin A2 + \frac{W \cos B}{Va1}$$

$$\frac{Vg2 \sin A2}{Va1} = K1\ (1-D2^2) \sin A2 + K1 \cdot D2 \cos A2 + \frac{W \sin B}{Va1}$$

$$\frac{Vg3 \cos A3}{Va1} = K2\ (1-D3^2) \cos A3 - K2 \cdot D3 \sin A3 + \frac{W \cos B}{Va1}$$

$$\frac{Vg3 \sin A3}{Va1} = K2\ (1-D3^2) \sin A3 + K2 \cdot D3 \cos A3 + \frac{W \sin B}{Va1}$$

Now let

$$X1 = D1 \quad (6)$$

$$X2 = D2$$

$$X3 = D3$$

$$X4 = \frac{W \cos B}{Va1}$$

$$X5 = \frac{W \sin B}{Va1}$$

$$X6 = \frac{1}{Va1}$$

Then in matrix form equations (6) substituted in (5) yield:

$$\begin{bmatrix} -\sin A1 - X1\cos A1 & 0 & 0 & 1 & 0 & -Vg1\cos A1 \\ \cos A1 - X1\sin A1 & 0 & 0 & 0 & 1 & -Vg1\sin A1 \\ 0 & -K1\sin A2 - K1\cdot X2\cos A2 & 0 & 1 & 0 & -Vg2\cos A2 \\ 0 & K1\cos A2 - K1\cdot X2\sin A2 & 0 & 0 & 1 & -Vg2\sin A2 \\ 0 & 0 & \begin{matrix}-K2\sin A3 \\ -K2\cdot X3\cos A3\end{matrix} & 1 & 0 & -Vg3\cos A3 \\ 0 & 0 & \begin{matrix}K2\cos A3 \\ -K2\cdot X3\sin A3\end{matrix} & 0 & 1 & -Vg3\sin A3 \end{bmatrix} \begin{bmatrix} X1 \\ X2 \\ X3 \\ X4 \\ X5 \\ X6 \end{bmatrix} \begin{bmatrix} -\cos A1 \\ -\sin A1 \\ -K1\cos A \\ -K1\sin A \\ -K2\cos A \\ -K2\sin A \end{bmatrix} \tag{7}$$

These equations are nonlinear because the determinent contains terms of the form X1 cos A1 and X1 sin A1. However, since X1, X2, and X3 are the drift angles which are small, these terms are small. Therefore, an iterative approach can be used to solve the equations. For the first trial solution, the values of X1, X2, and X3 used to compute the terms in the determinent can be set to zero. The resulting solutions for X1, X2, and X3 can then be used in a second trial solution to yield more accurate values. One iteration should give the accuracy desired. The value of Va1 computed in the first trial can also be used to improve the accuracy of K1 and K2.

3.10.2 True Airspeed Variation Measurement

With constant power settings on the engines of a fixed wing aircraft, the true airspeed should remain approximately constant over the measurement period. However, the pilot of the helicopter determines the power used for thrust and therefore, the true airspeed. As a result, small variations in true airspeed should be expected during the wind measurement period.

The desired accuracy can most easily be achieved if true airspeed variations are measured from the airspeed value existing at the time of measuring Vg1, rather than measuring absolute values of true airspeed at each point. Let Va2 in equation (3) be expressed as Va2 = Δ Va2. Then K1 can be defined as

$$K1 = \frac{Va2}{Va1} = 1 + \frac{\Delta Va2}{Va1} \tag{8}$$

The error δ K1 in K1 that results from errors δ Va1 in Va1 and δ Δ Va2 in Δ Va2 can be expressed as

$$\delta K1 = \frac{1}{Va1}\,\delta\,\Delta\,Va2 - \frac{\Delta Va2}{(Va1)^2}\,\delta\,Va1 \tag{9}$$

This indicates that an accurate knowledge of the absolute value of true airspeed is not required.

Example: $Va1 = 100$ kts

$\Delta Va2 = 10$ kts

$\delta \Delta Va1 = \delta \Delta Va2 = 1$ kt

Then

$$\delta K1 = \frac{1}{100}(1) - \frac{10}{(100)^2}(1)$$

or

$$\delta K1 = \underbrace{0.01}_{\text{Due to } \delta \Delta \text{ Va2}} - \underbrace{0.001}_{\text{Due to } \delta \text{ Va1}}$$

A possible circuit to measure changes in true airspeed is shown as figure 3-59. True airspeed is assumed to be available as a dc voltage. In normal operation operational amplifier No. 2 cancels the true airspeed input to amplifier No. 1. During the wind measurement period the hold switch is opened and amplifier No. 2 provides a memory of Va1. Therefore the output of amplifier No. 2 becomes Δ Va and can be measured when other groundspeed measurements are made. A typical range of operation for the system could be

$$-8 \text{ kts} < \Delta \text{ TAS} < +8 \text{ kts}$$

Then, a 6-bit digital conversion would give a maximum 0.25 kt. quantization error. Further, if true airspeed is known to 5 percent, then the error in ΔVa at the limit is 5 percent of 8 knots, or 0.2 knot.

3.10.3 Measurement Parameter Study

The accuracy of wind determination by this method is a function of the bearings at which the three groundspeeds are measured and the errors in the measurements. A digital computer study is in process to establish the relationships. The results will be reported when available.

Based on the determination of wind data from ground speed measurements as previously described, the decision was made on 25 Apr 67 to add a wind calibration mode to the system. Experience has shown that true airspeed would vary significantly (± several knots) during the calibration period. Therefore the variation of true airspeed between the points at which ground speed is recorded would have to be measured.

The implementation procedures for the wind calibrate mode follow:

3.10.4 Equipment Configuration

The equipment configuration required to implement this decision is illustrated in figure 3-60. Most of the components already existed in the system. The amplifier was mounted in Pod 1 in the multiplexer. The switches were mounted on the system control panel in the aircraft. One of the computer output lamps was required to indicate if the wind calibration

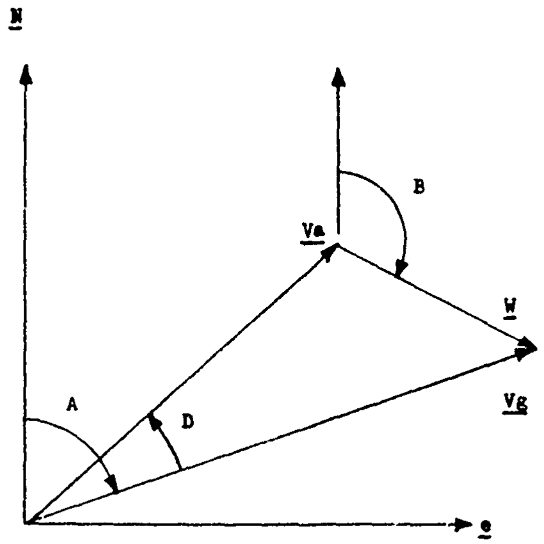


Figure 3-58. Vector Diagram for Groundspeed, True Airspeed, and Wind.

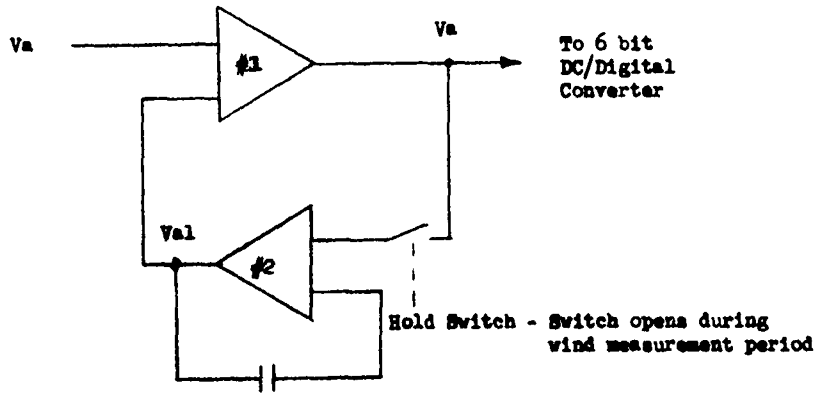


Figure 3-59. True Airspeed Variation Measurement.

process was successful. In addition to the hardware changes, a special wind calibration mode program had to be written for the digital computer to process the data properly.

The true airspeed amplifier was scaled for ±2.5 volts for ±8 knots, which resulted in a digital quantization of 0.25 knot in the converter. The input to the amplifier from the MRI instrument convered a range of 0 to 250 mph with a voltage range of 0 to 5 volts dc.

The discrete control inputs through the multiplexer were combined with discrete input No. 12 which resulted in a once per second read rate. A separate wind calibrate mode switch was used since the wind calibration process can be accomplished with the system operating normally.

3.10.5 System Operation in Wind Calibration Mode

At the start of a wind calibration maneuver, the mode switch had to be in the OFF position for several seconds to allow the true airspeed amplifier output to stabilize. The operator then turned the wind calibrate mode switch (S1) ON and the wind read switches (S2, S3, S4) to the OFF positions. If the computer sensed that the switches were in the proper positions to start a wind maneuver, the wind mode indicator lamp would be left off. Otherwise, it would be turned on indicating a fault in procedure. Any time that the switches were returned to this starting position, the computer program would be initialized and the lamp turned off, which made it easy to start over if a fault occurred in the sequence.

The aircraft was then flown to acquire groundspeed, airspeed variation, and navigator wind data on three separate legs of a wind maneuver course. An error analysis indicated that these legs should be on headings separated by at least 90 degrees. On the first leg, several seconds were allowed to stabilize the flight conditions and the navigator wind solution. The operator then set the Read 1 switch ON. This caused the computer to record groundspeed, ground track, true airspeed variation, wind north, and wind east as one data set. The aircraft then turned to new headings and the process was repeated for a second and a third data point with the Read 2 and Read 3 switches providing the control indications.

After the third point was read into the computer, the wind calibration program calculated a wind vector based on the three data sets. This solution was compared with the navigator wind data at the three points, and a yaw and a true airspeed calibration factor was calculated for each point. If these were within 3 knots of each other, the calibration was considered successful and average factors were stored for use in correcting future wind data from the navigator. If the comparison failed, the wind mode indicator lamp was turned on indicating that the maneuver had to be repeated. The fault lamp also turned on if an improper sequence was sensed or if the true airspeed input was out of limits.

The success of the calibration process depended on the existence of a steady wind over the maneuver period. Therefore, the aircraft had to be flown at a high enough altitude to achieve this as indicated by a low level of turbulence.

3.10.6 Sensitivity of the Wind Calibrate Mode Solution for Wind Vector to Measurement Errors and Course Geometry.

A digital computer study was conducted to determine the effects of measurement errors on the solution for the wind vector in the wind calibration mode for various sets of flight course geometries.

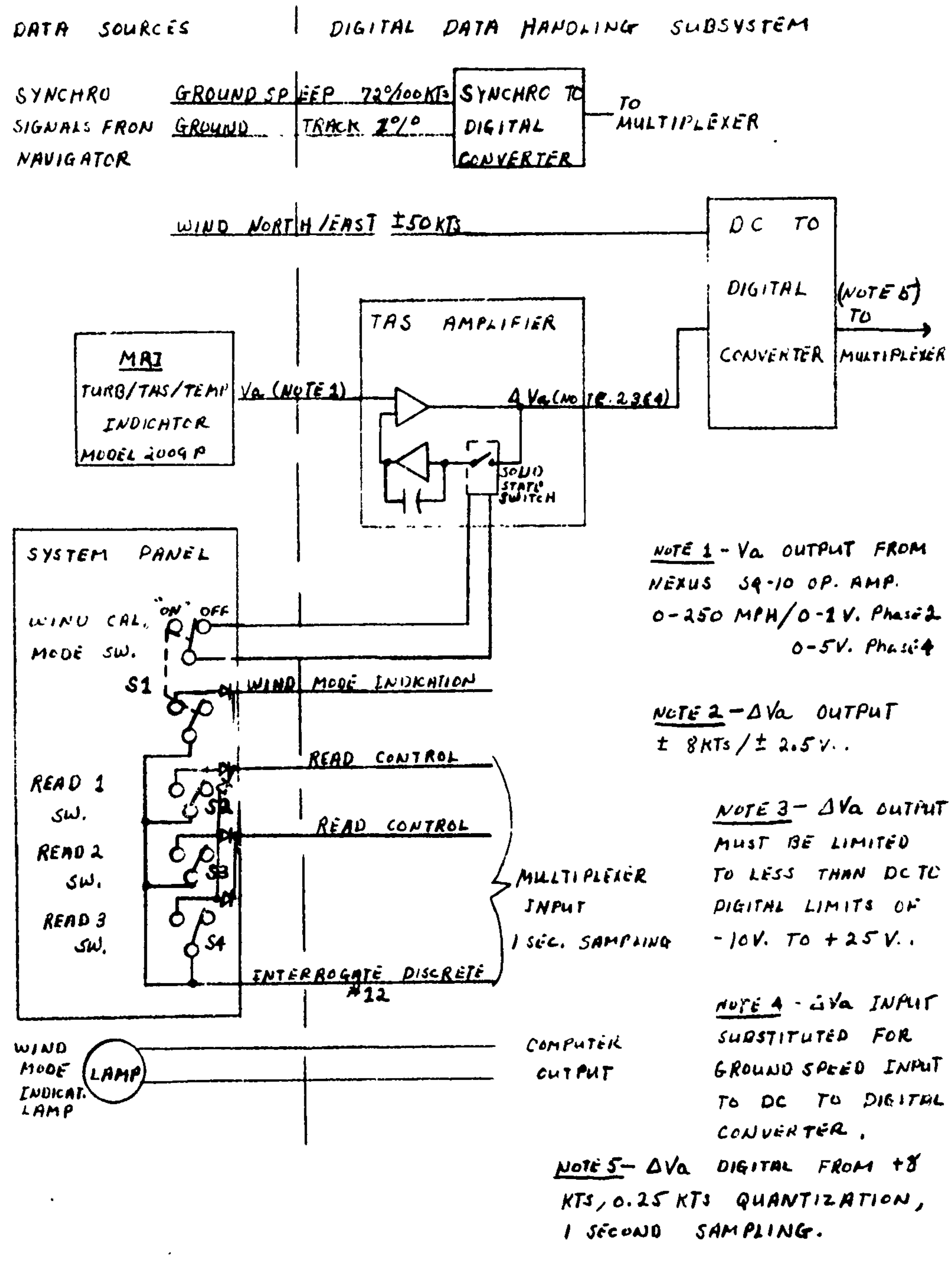


Figure 3-60. Wind Calibration Mode Equipment Configuration.

3.10.6.1 Conclusions: The calculations show that the error in the wind solution increases rapidly as the angles decrease between the three legs of a course on which a set of data is recorded. Therefore the three legs of the calibration course should be separated by about 90 degrees as a minimum. The errors are insensitive to other course geometry factors such as true airspeed, orientation of the three legs with respect to the wind vector, and wind velocity.

It is desirable to limit the error in calculated wind to less than one knot due to measurement errors. A set of error allocations that will do this are 0.5 knot in groundspeed, 2 degrees in ground track, and one knot in true airspeed variation.

3.10.6.2 Description of Calculations. Calculations were performed for wind velocities of 10, 20, and 30 knots and true airspeeds of 50, 100, and 150 knots. Three true airspeed vector directions equally spaced in angle were used with each combination of these. The angular spacing was varied from 30 degrees to 120 degrees. Two orientations of the central true airspeed vector were used. In the first this vector was aligned along the wind vector while in the second it was perpendicular to the wind vector.

For each of the cases defined, errors were individually introduced in each input quantity and the resultant wind speed vector calculated. This, in effect, determines the partial derivative error coefficient for each parameter. Errors of one knot were introduced in each groundspeed and true airspeed variation velocity. An error of one degree was added to each ground track angle.

3 10.6.3 Results of Calculations. The results are presented chiefly as curves of the error coefficients along and perpendicular to the true wind vector plotted against the angles between the true airspeed vectors.

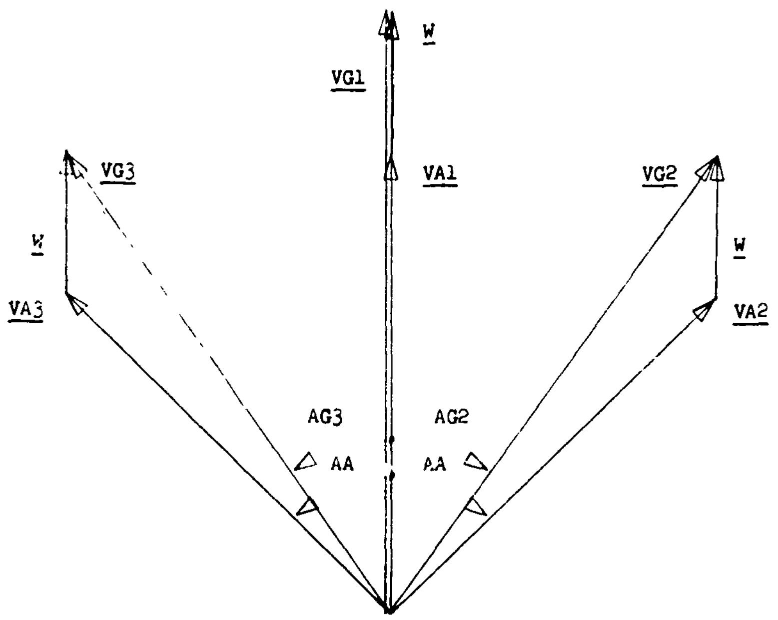
The results have been divided into two classes based on the direction of the central true airspeed vector.

3.10.6.3.1 Class I—Central True Airspeed Vector Along Wind Vector. The geometrical relationships for this class of courses is shown as figure 3-61. The true airspeed vector has an angle of either 0 or 180 degrees with the wind vector. Due to the symmetry of the situation errors of equal magnitude are produced by errors in groundspeeds VG2 and VG3 by errors in ground track angles AG2 and AG3, and by errors in true airspeed variations ΔVA2 and ΔVA3. Therefore a single plot is used for each set.

The error coefficients for groundspeed VG1 are presented on figure 3-62, while that for groundspeeds VG2 and VG3 are plotted in figure 3-63. The error coefficients for ground track angle AG1 are plotted in figure 3-64, with those for ground track angles AG2 and AG3 plotted in figure 3-65. Figure 3-66 shows the error coefficients for true airspeed variations ΔVA2 and ΔVA3.

3.10.6.3.2 Class II—Central True Airspeed Vector Perpendicular to Wind Vector. The geometrical relationships for this class of courses are shown as figure 3-67. Examination of the data showed that the error coefficients for VG2 and VG3, AG2 and AG3, and ΔVA2 and ΔVA3 were very nearly the same. Therefore, single plots have been made for each of these sets of conditions.

The data for groundspeed VG1 is plotted in figure 3-68, with that for groundspeeds VG2 and VG3 plotted in figure 3-69. Figure 3-70 shows the error coefficients for ground track angle AG1 while figure 3-71 shows those for ground track angles AG2 and AG3. The error coefficients for true airspeed variations ΔVG2 and ΔVG3 are presented in figure 3-72.



NOMENCLATURE

VA - True Airspeed Vector
AA - True Airspeed Angular Spacing
W - Wind Vector
VG - Groundspeed Vector
AG - Ground Track Angle

Figure 3-61. Course Class 1 Vector Diagram.

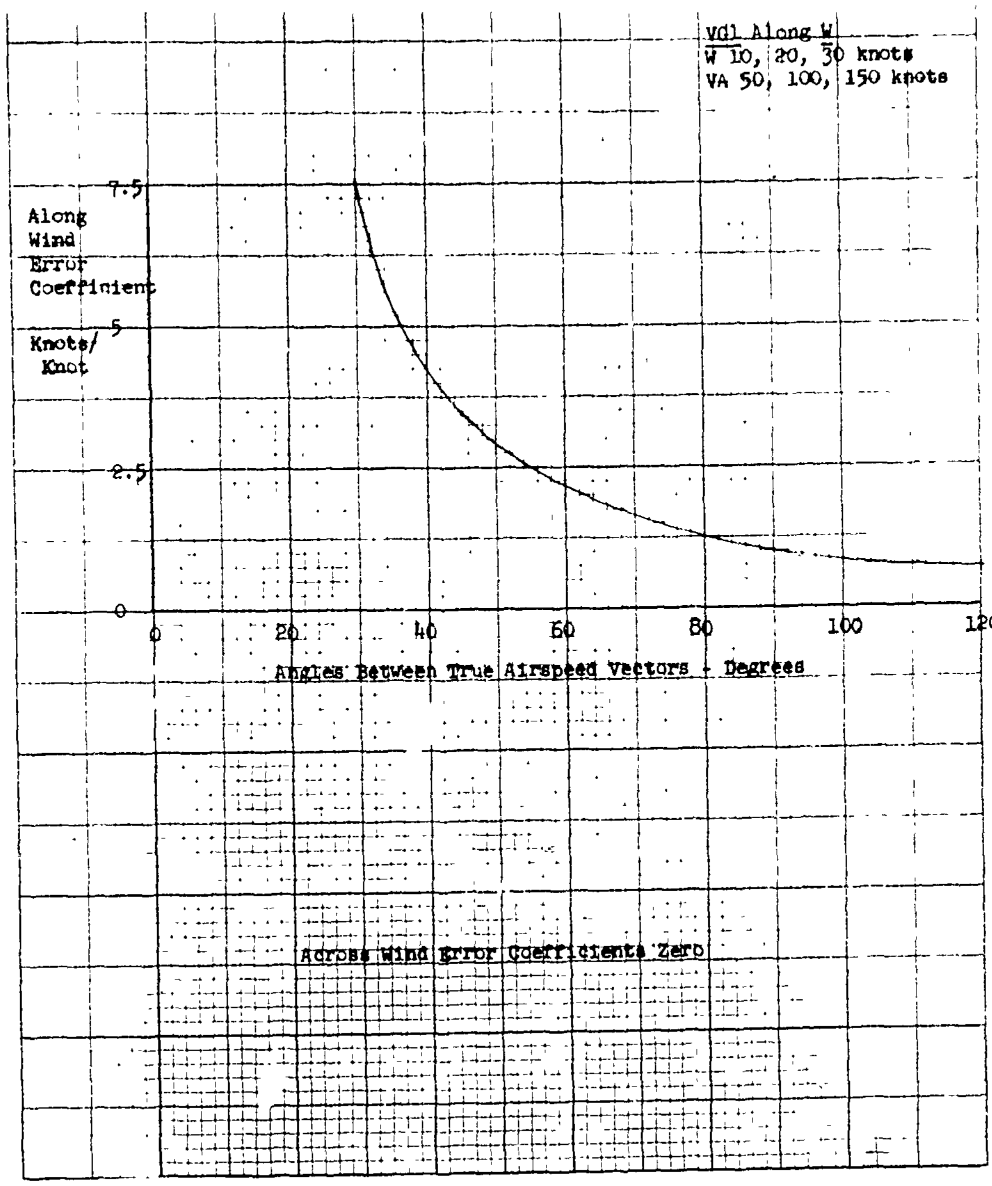


Figure 3-62. Error Coefficients for Error in VG1 Magnitude.

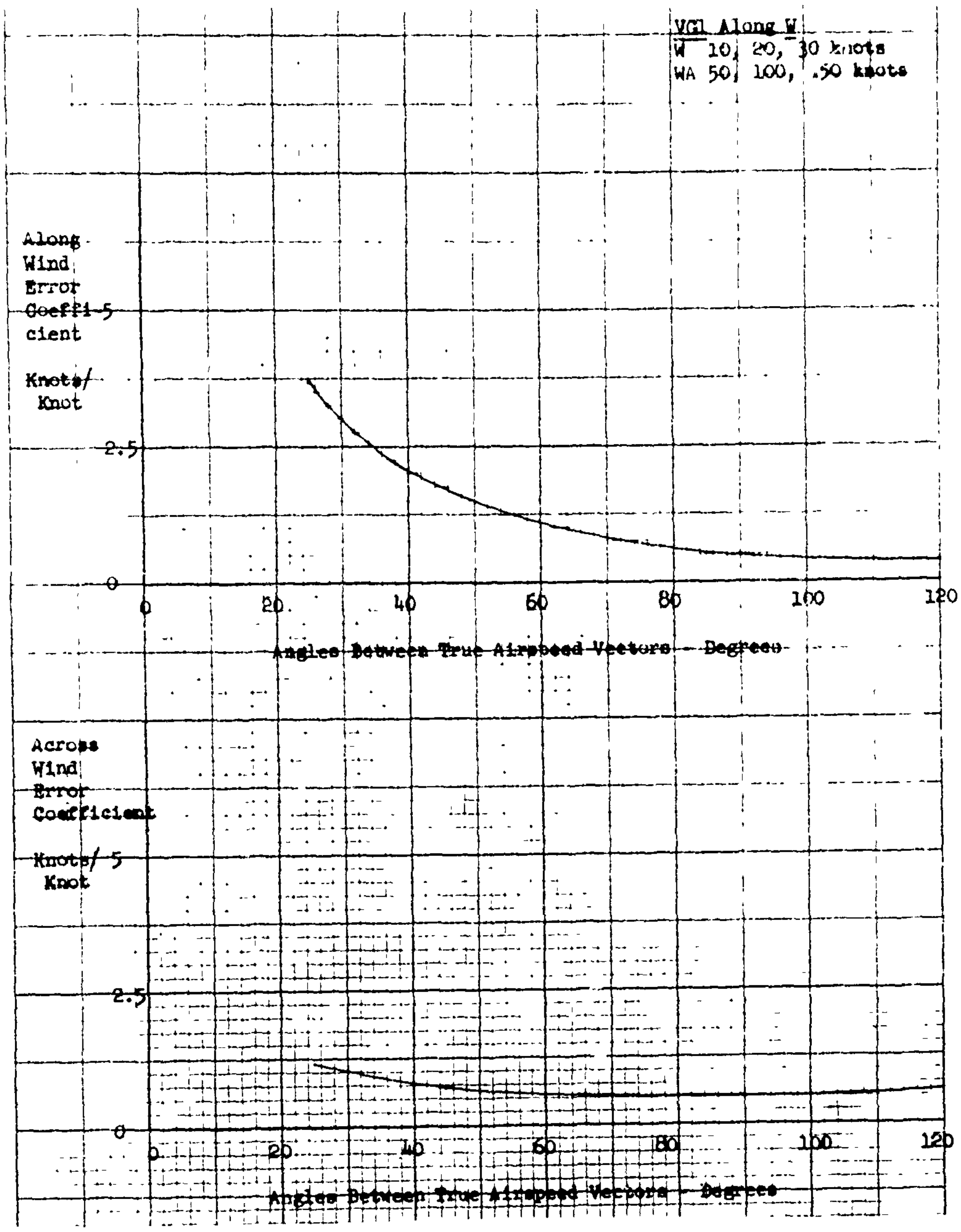


Figure 3-63. Error Coefficients for Error in VG2 or VG3 Magnitudes.

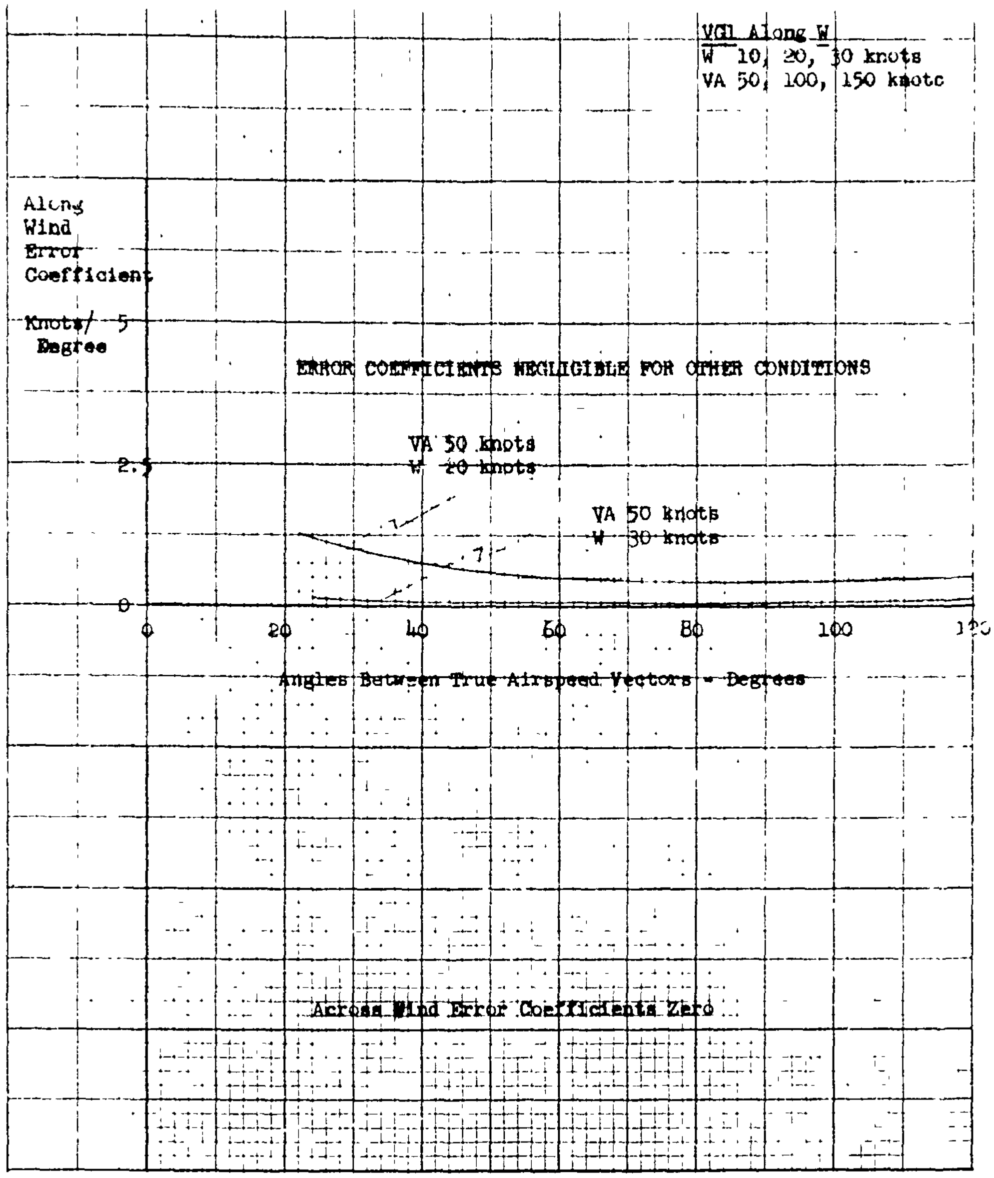


Figure 3-64. Error Coefficients for Error in Ground Track Angle AG1.

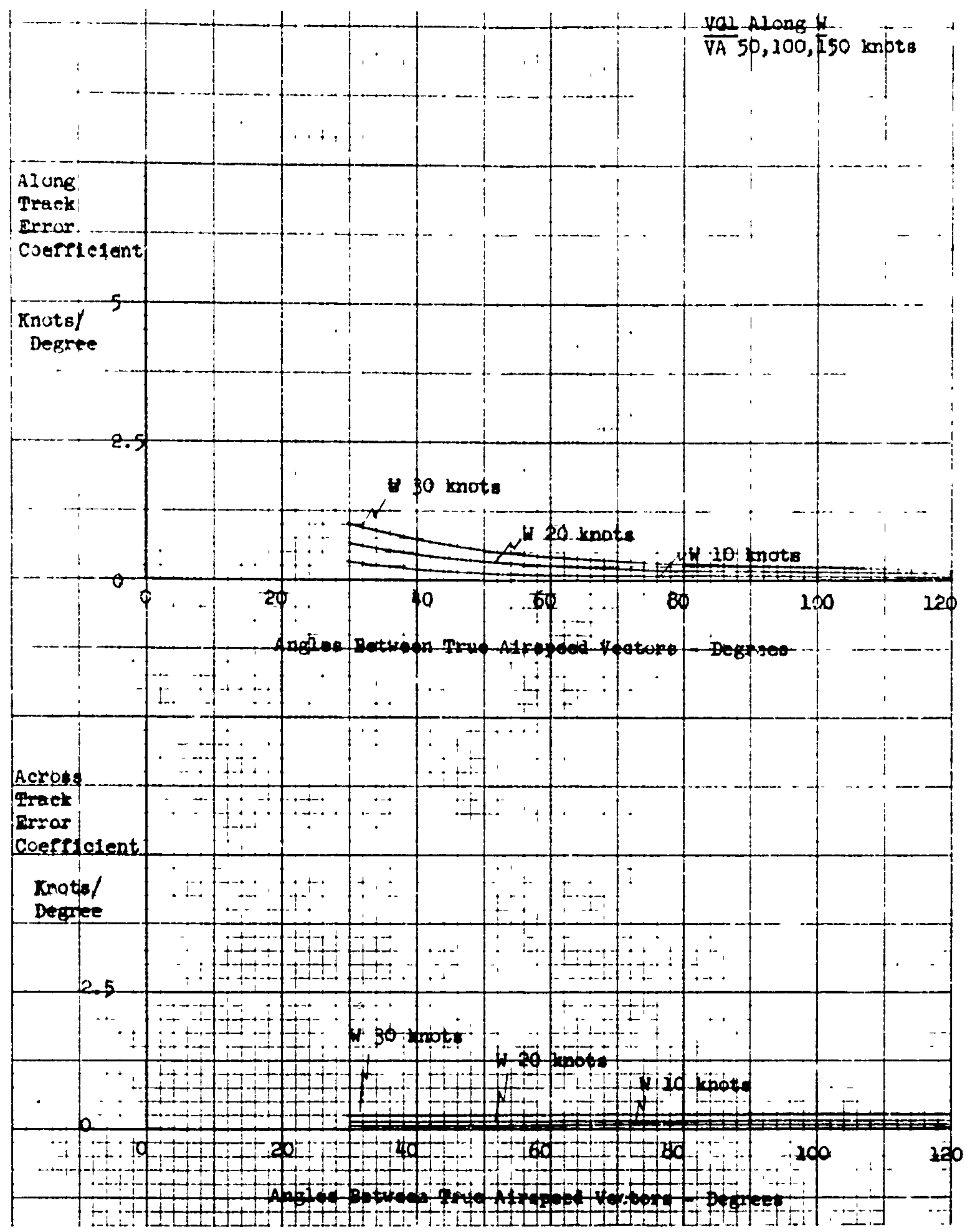


Figure 3-65. Error Coefficients for Error in Ground Track Angles AG2 or AG3.

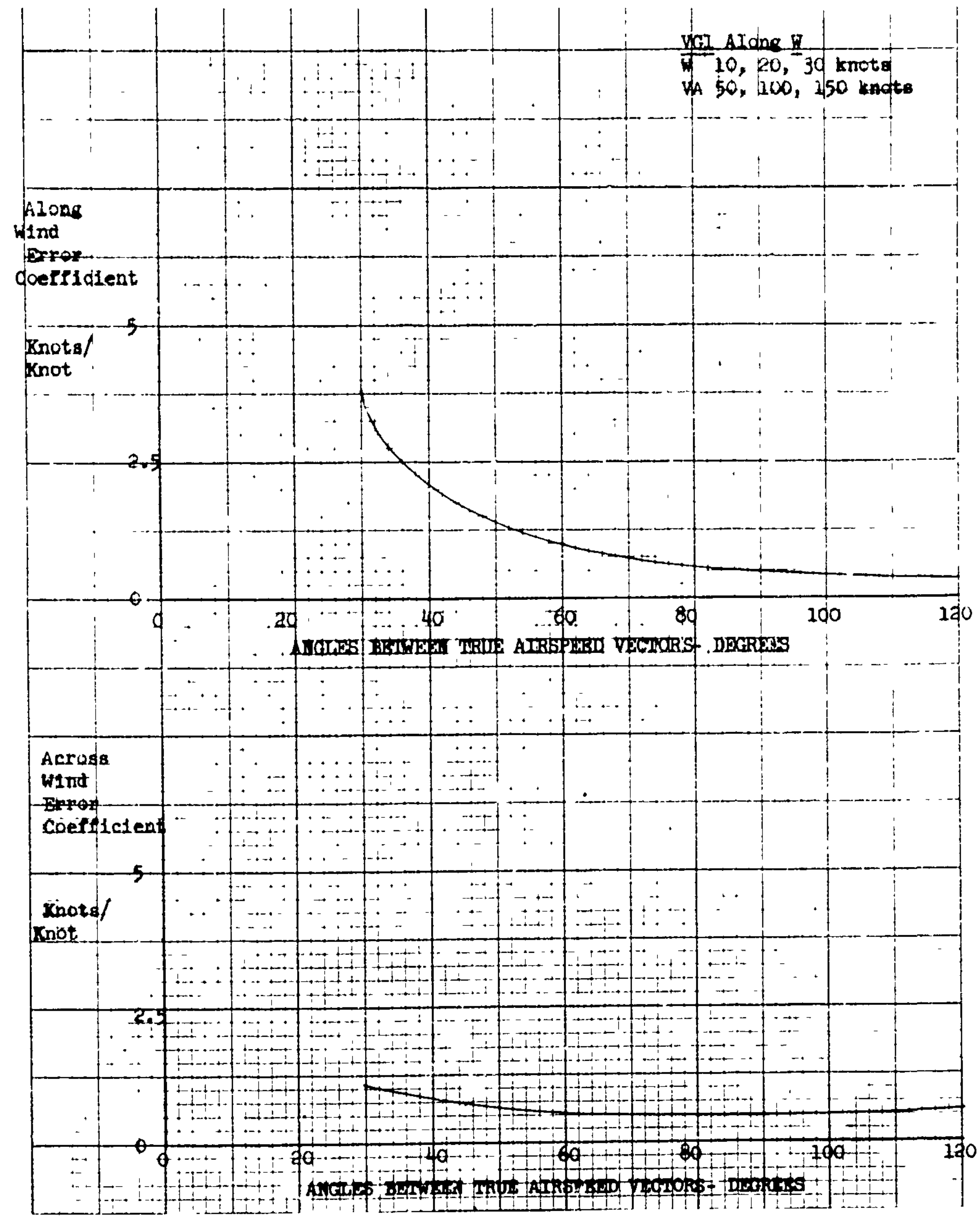
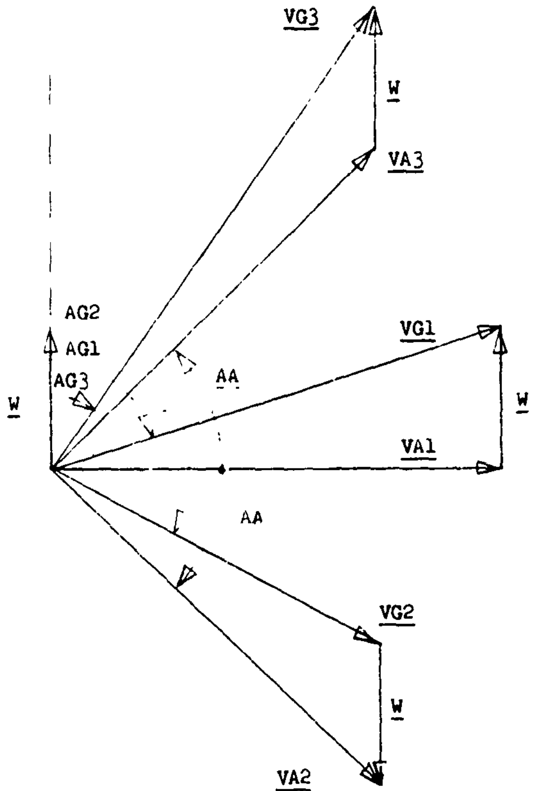


Figure 3-66. Error Coefficients for Error in ΔVA2 or ΔVA3 Magnitudes.



NOMENCLATURE

VA - True Airspeed Vector
AA - True Airspeed Angular Spacing
W - Wind Vector
VG - Groundspeed Vector
AG - Ground Track Angle

Figure 3-67. Course Class 2 Vector Diagram.

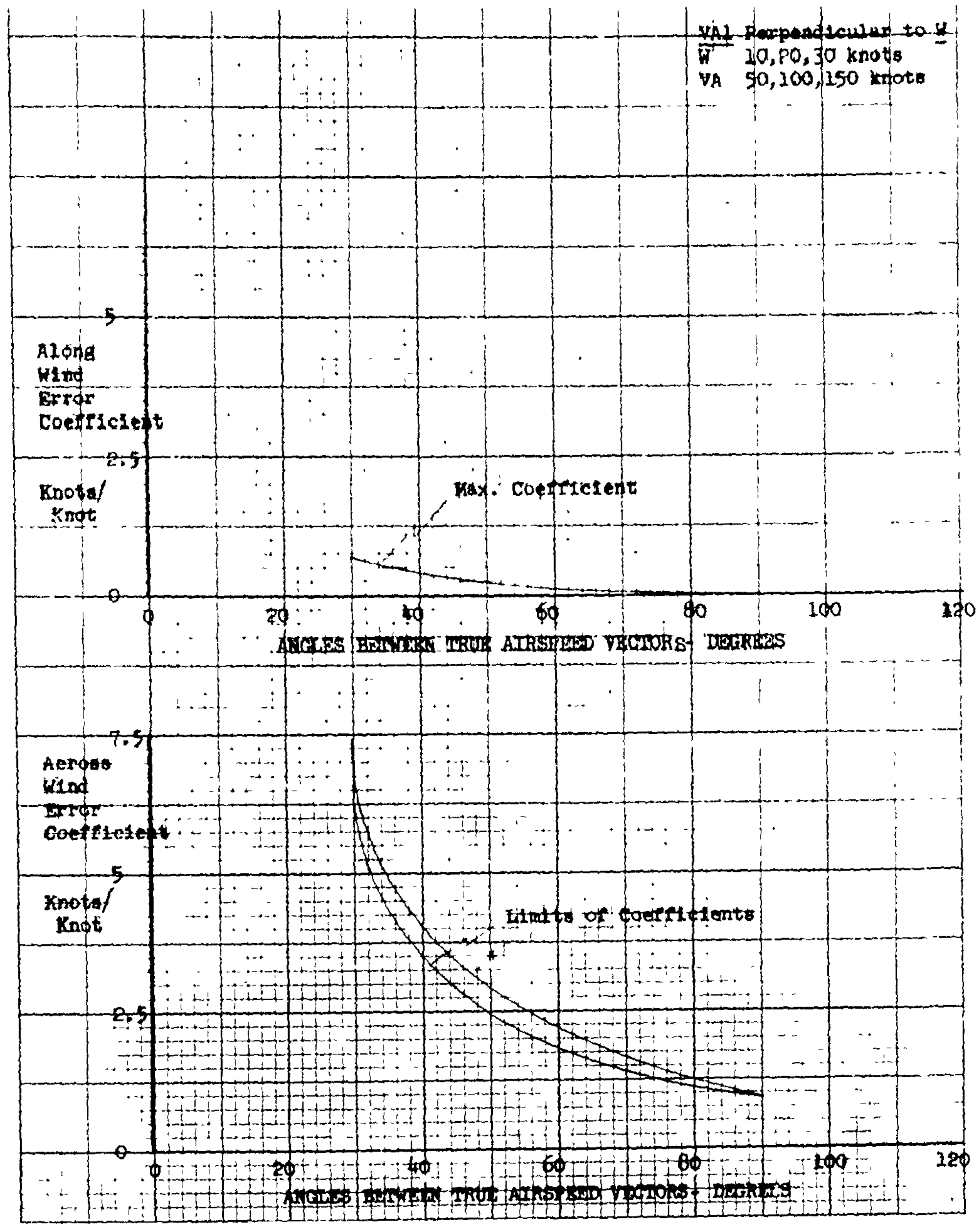


Figure 3-68. Error Coefficients for Error in VG1 Magnitude.

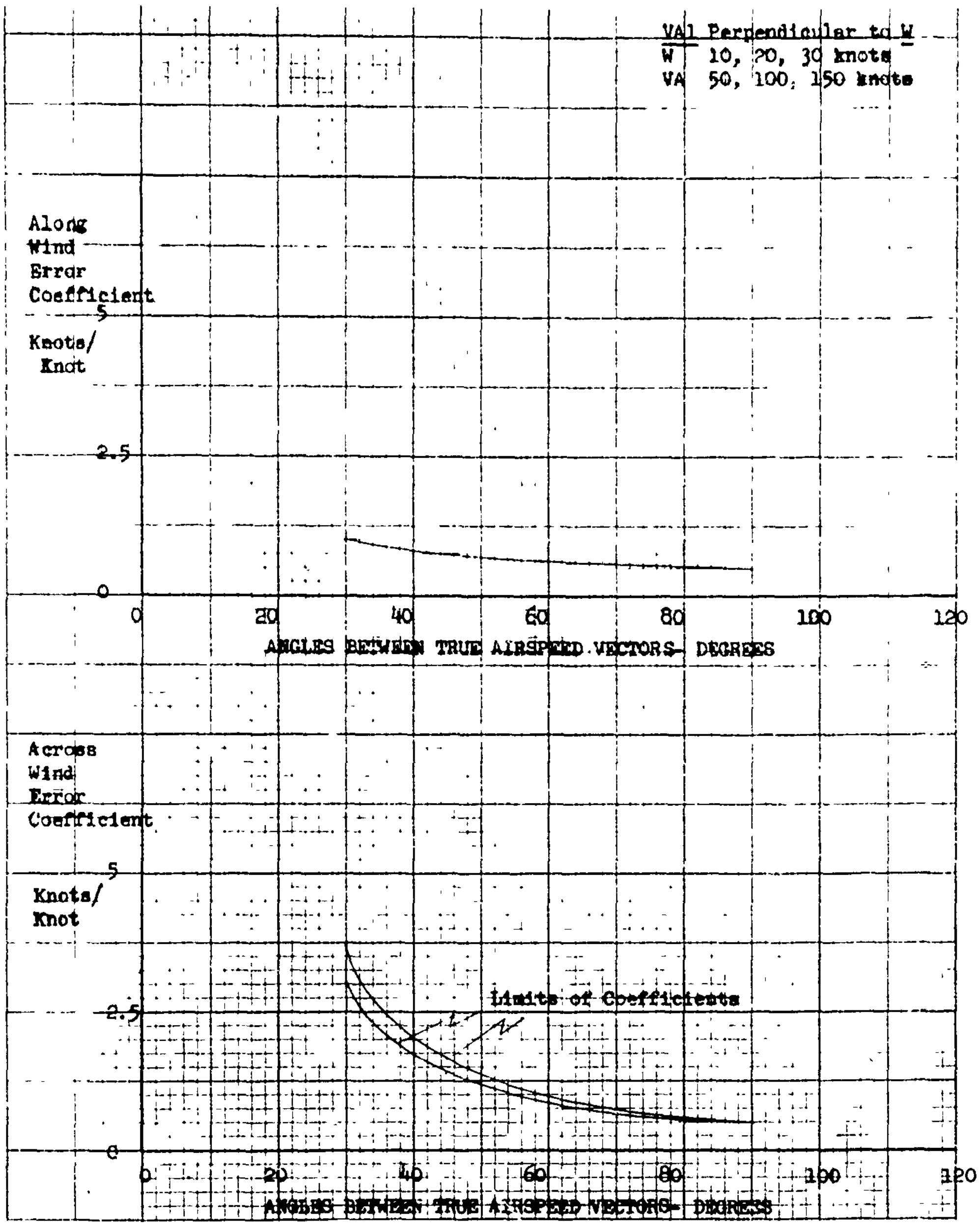


Figure 3-69. Error Coefficients for Error in VG2 and VG3 Magnitudes.

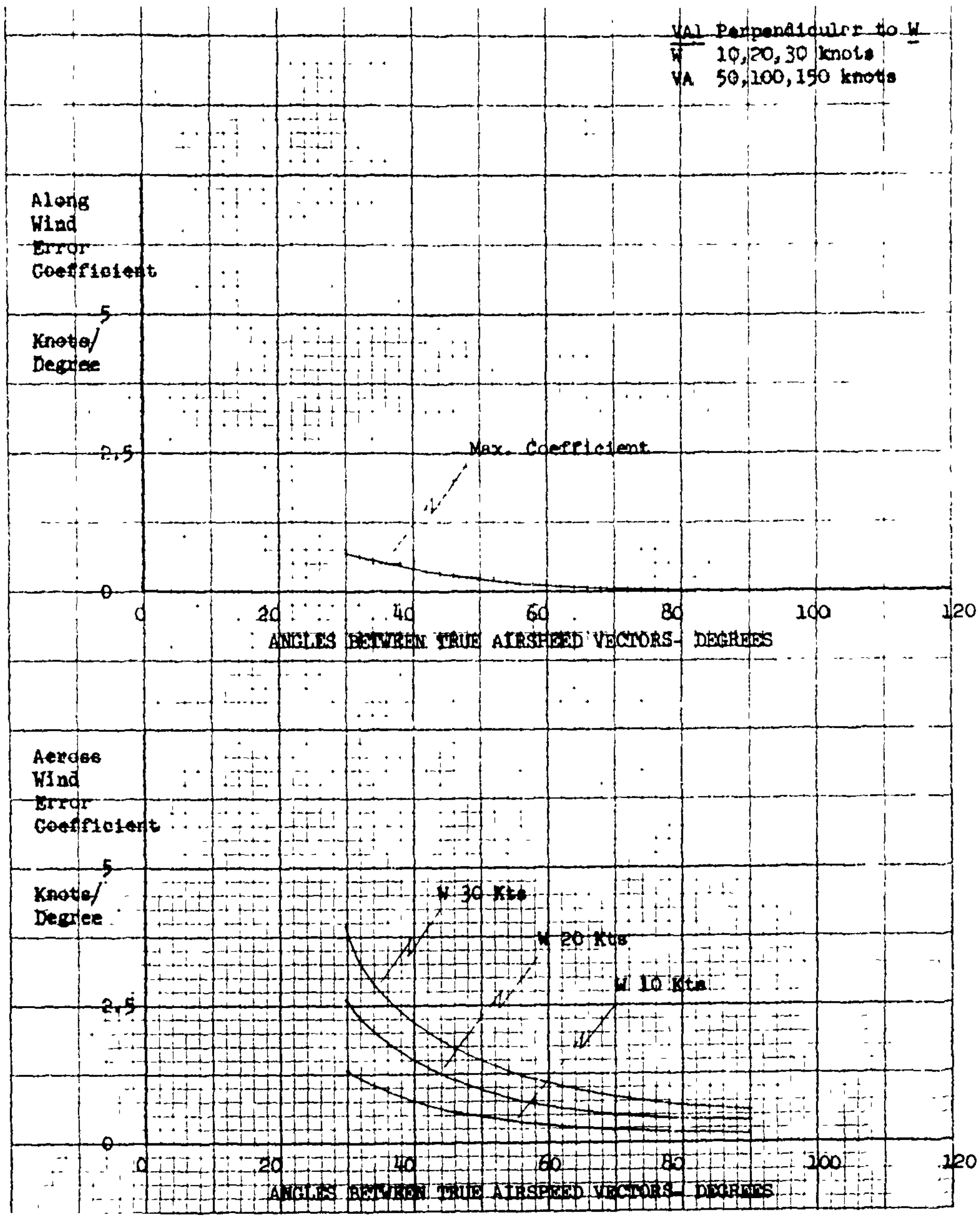


Figure 3-70. Coefficients for Error in Ground Track Angle AG1.

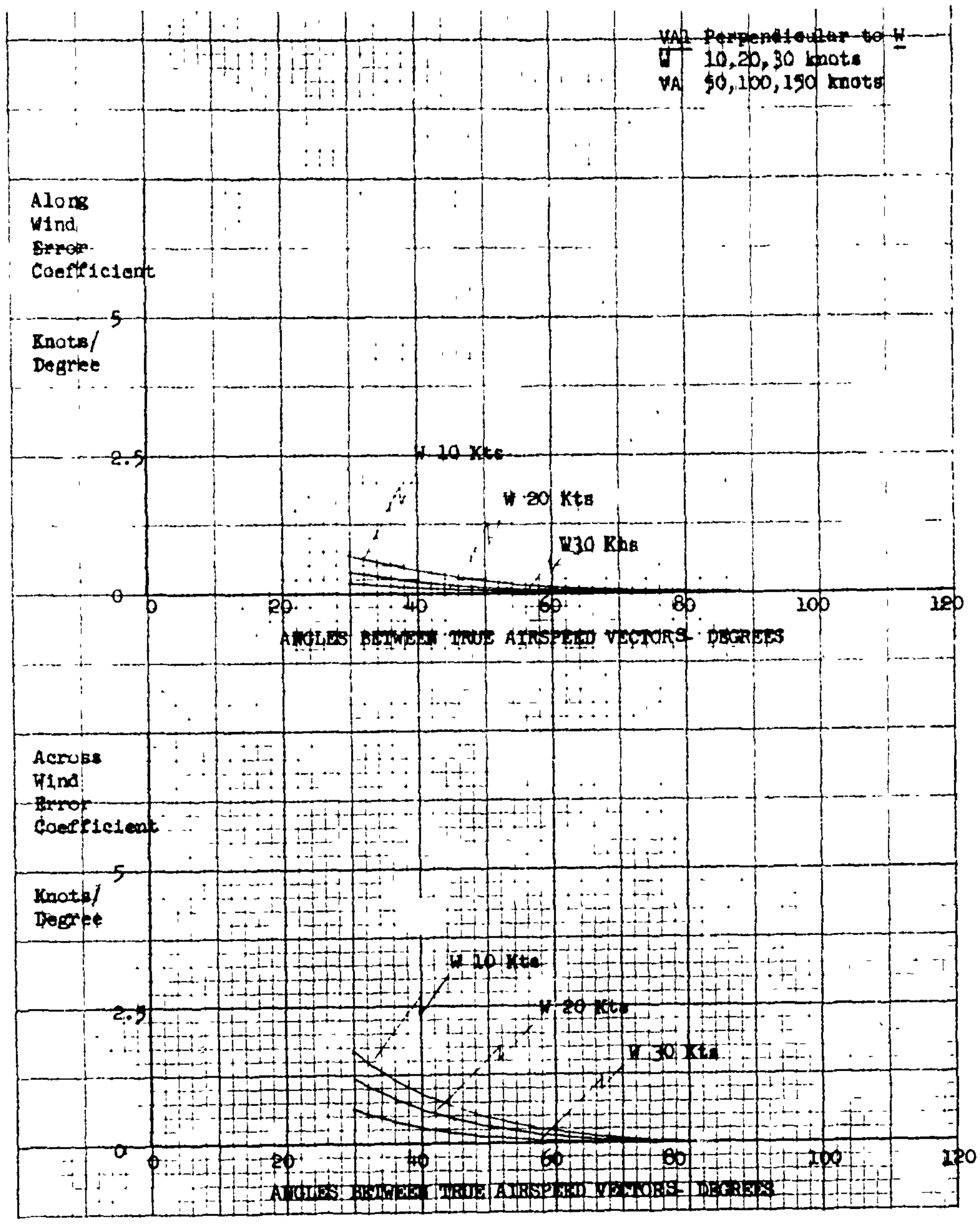


Figure 3-71. Coefficients for Error for Ground Track Angies AG2 and AG3.

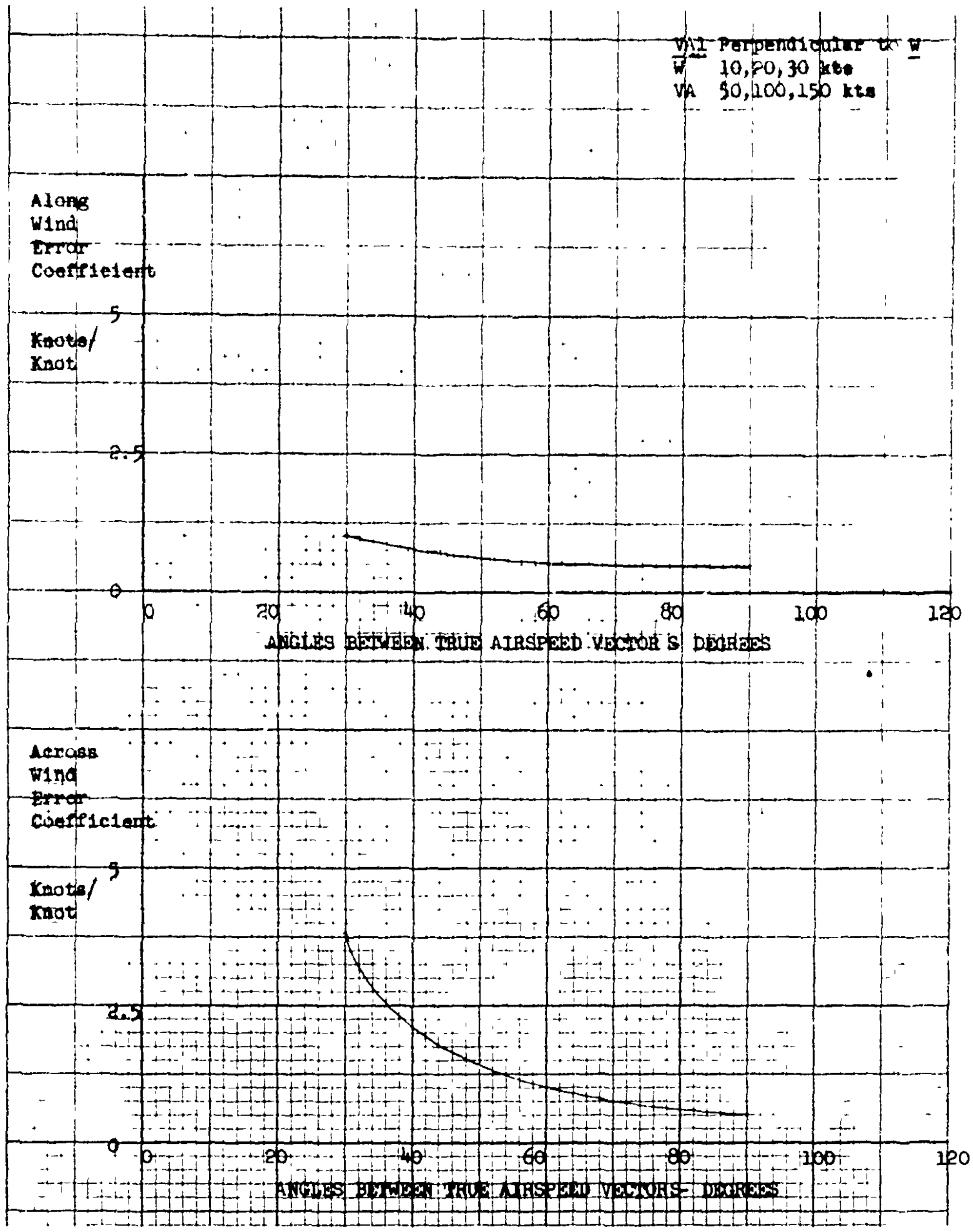


Figure 3-72. Coefficients for Error in ΔVA2 or ΔVA3 Magnitudes.

3.11 FIELD TESTING/SYSTEM 1

The initial field testing was conducted at Homestead Air Force Base, Homestead, Florida from 16 Mar 68 to 25 Mar 68.

The OV-1 aircraft arrived on 13 Mar 68. Initial problems were experienced with the navigator, compass swing, recorder, yaw sensor, and turbulence sensor. True airspeed was trimmed to improve the wind solution. During the final week, successful navigation missions were flown with an operating plotter, and the aircraft was flown on the grid with successful CN detections being made. Offset plotting of sources was a problem due to the many detections of signals not associated with the specified source.

3.11.1 Equipment Problems

Equipment problems which occurred during the field test follow:

1. Doppler Navigation Set

   a. Incorrect wind solution due to mix up in connecting connector to side-slip sensor. Corrected.

   b. Navigation set failed to lock-on while in flight due to water in the antenna compartment. Corrected.

   c. Incorrect wind solution due to a broken wire on the side-slip sensor connector. Corrected.

   d. Incorrect wind solution due to misalignment of synchro to side-slip sensor case. Placed jumper in connectors to bypass side-slip sensor.

2. Turbulence Sensor. The small propellor repeatedly broke on the OV-1. (Corrective design action is required.)

3. Digital Multiplexer, Computer and Digital Converters. No operating problems occurred.

4. Control Station. No operating problems occurred.

5. Plotter. Jerky operation was observed at the borders. LORAL support personnel determined that the problem was caused by a ground voltage offset due to current in the ground return and took action to correct it.

6. Analyzer. Some failures occurred with the analyzer and were corrected. The design should be modified for a minimum background level in order to prevent false triggering by noise at low background levels.

7. Kennedy Recorders (OV-1 S/N 5). A faulty capacitor (C13) on the gap generator CA type 1660 board was found and replaced; however, the recorder operated normally for the rest of the test.

8. Recorders S/N 5, 6, 7. The cartridge sensing switches on all recorders was jumpered out because cartridge vibration was causing an interlock alarm. The front shock mounts on the recorders were insufficient causing excessive vibration to UH-1D recorder.

9. S/D, A/D and D/A Converters No Failures.

10. Software

   a. Tactical Program. The tactical program performed without any detectable problems.

   b. Tapes. Three days were spent at Ft. Lauderdale setting up tape reading procedures and correcting the tape printout format errors. Five good 0V-1 flight tapes were made on five days starting 19 Mar 68 through 23 Mar 68.

3.11.2 Corrective Design Problems

Equipment problems that require corrective design action were defined for the following items.

1. Detector. The present detector has major design deficiences that must be corrected. These resulted in noisy operation and severe loss of sensitivity with operating time. Suggested possible causes were valve flaking, water in chamber, poor humidifier action, and considerable temperature rise of the detector block.

2. Converter. The present converter did not operate at relative humidities below 60-70 percent, and perhaps not at temperature below 60 deg F. A development effort should be started to design a converter with humidification.

3. Navigator. Continuous efforts of two men were required to keep the 0V-1 and UH-1 navigators working. The compass on the 0V-1 required a 4-degree easterly variation for proper navigation. This was a 3.5-degree easterly correction for compass error. Also, the yaw sensor synchro zero shifted 4 degrees. As a result, it was not used. Also, the control indicator present position readout must be aligned to the synchro readout.

4. Digital Tape Recorder. A design problem was uncovered on the cartridge sensing switches that must be corrected; this must be investigated further with vibration testing.

5. Turbulence Sensor. The propeller for the turbulence sensor was inadequate for 0V-1 air speeds. New propellers should be ordered.

3.11.3 J0V1-B Flights/Day-by-Day

A day by day account of all J0V1-B (27) flights, including object, flight plan, plotter maps and results, follows.

3.11.3.1 Flight 1/14 Mar 68.

Object: This initial flight was intended to determine the status of the system and identify problem areas.

Results: The temperature reading was negative on the meteorological microammeter.

No fluctuations in turbulence were noted throughout the flight.

The navigator failed to lock-on in LAND mode.

The wind solution on the VSI was constantly slewing

Problem Causes: The temperature was not reading correctly because the connection between the temperature sensing thermocouple and the MRI was not made.

Turbulence was constant because the turbulence mode switch was in the calibrate position.

The navigator failure to lock-on and the slewing of wind on the VSI were caused by a reversal between the true airspeed transmitter and the side slip sensor cables in Pod 2.

3.11.3.2 Flight 2/14 Mar 68.

Object: This flight was flown by Major D. Clark and a visiting Army officer. During the flight, the system was exercised.

Results: The wind solution indicated on the VSI was incorrect.

The plotter was tracking 90 degrees out of phase with the aircraft ground track.

Recorder was not working.

Problem Causes: The TAS transmitter control differential synchro was recalibrated for a true airspeed of 150 kts, considered to be the cause of the incorrect wind solution.

The plotter action was explained by the fact that in STBY mode, the plotter bug will slew only North and East. A check of the plotter indicated proper operation when the navigator was in LAND or AIR modes.

The recorder could not be turned on because there was no tape cartridge in the recorder and the interlocks were not engaged.

3.11.3.3 Flight 3/15 Mar 68.

Object: Fly a predetermined course between established check points and check the navigation accuracy of each check point.

Determine the accuracy of the navigator wind solution by holding indicated true airspeed constant and noting the groundspeed while flying in opposite directions

Results: The navigator would not lock-on in LAND mode. Auto-acquisition would not cause lock-on to occur.

Without navigator lock-on wind runs could not be made.

Problem Causes: The navigator would not lock-on because water in the radome.

With the aircraft on the ground, the pod's attitude was nose up and all the water accumulated at the rear of the radome. Under this condition, lock-on could be obtained. However, when the aircraft was airborne, the pod was level, and the water was distributed over the entire surface of the radome, thus preventing lock-on from occurring. To prevent future accumulation of water in the radome, a bolt in the aft portion of the radome was removed, and the gasket material was channeled in the region of the removed bolt. This drainage hole will prevent water from accumulating in the aft section of the radome while the aircraft is on the ground.

3.11.3.4 Flight 4/16 Mar 68 (Figure 3-73). Prior to flight 4, a preflight checkout indicated that the wind solutions were erratic. A broken wire was found in a connector leading to the side slip sensor output.

Object: Fly a closed navigation course to check navigator accuracy and determine the accuracy of the navigator wind solution.

Results: Navigator was found to be inaccurate with a variation set at zero.

Wind data was only taken twice and it appeared to be accurate at 150 kts and inaccurate at 190 kts.

The turbulence propeller lost two blades during the flight.

Problem Causes: The navigator inaccuracy was attributed to an improper setting of variation. It was decided to use a variation of 0.4 degree East on the next flight.

Because only two wind runs were made during the flight, there was not enough data to warrant any readjustment of the TAS transmitter control differential synchro.

It was found that the SSS synchro was out of alignment with the side-slip sensing element. The side-slip sensor was removed from the system.

The cause of the broken turbulence propeller was not determined, and the propeller was replaced.

3.11.3.5 Flight 5 (See Map)/16 Mar 68 (Figure 3-74).

Object: Fly a closed navigation course with a variation of 0.4 degree East to check navigator accuracy.

Run six wind checks at 150 kts and 190 kts.

Fly along Route 1 on the down-wind side of the road and check for C/N detections of automobile exhaust.

Results: The navigator maintained a cross-track error, although the along-track accuracy looked good.

The wind runs indicated that the wind solution was in error at 190 kts.

The turbulence propeller was again damaged during flight.

Recorder could not be turned on in flight.

Flight along Route 1 appeared to produce C/N detections on the analyzer microammeter. Because the recorder could not be turned, on this data was not recorded.

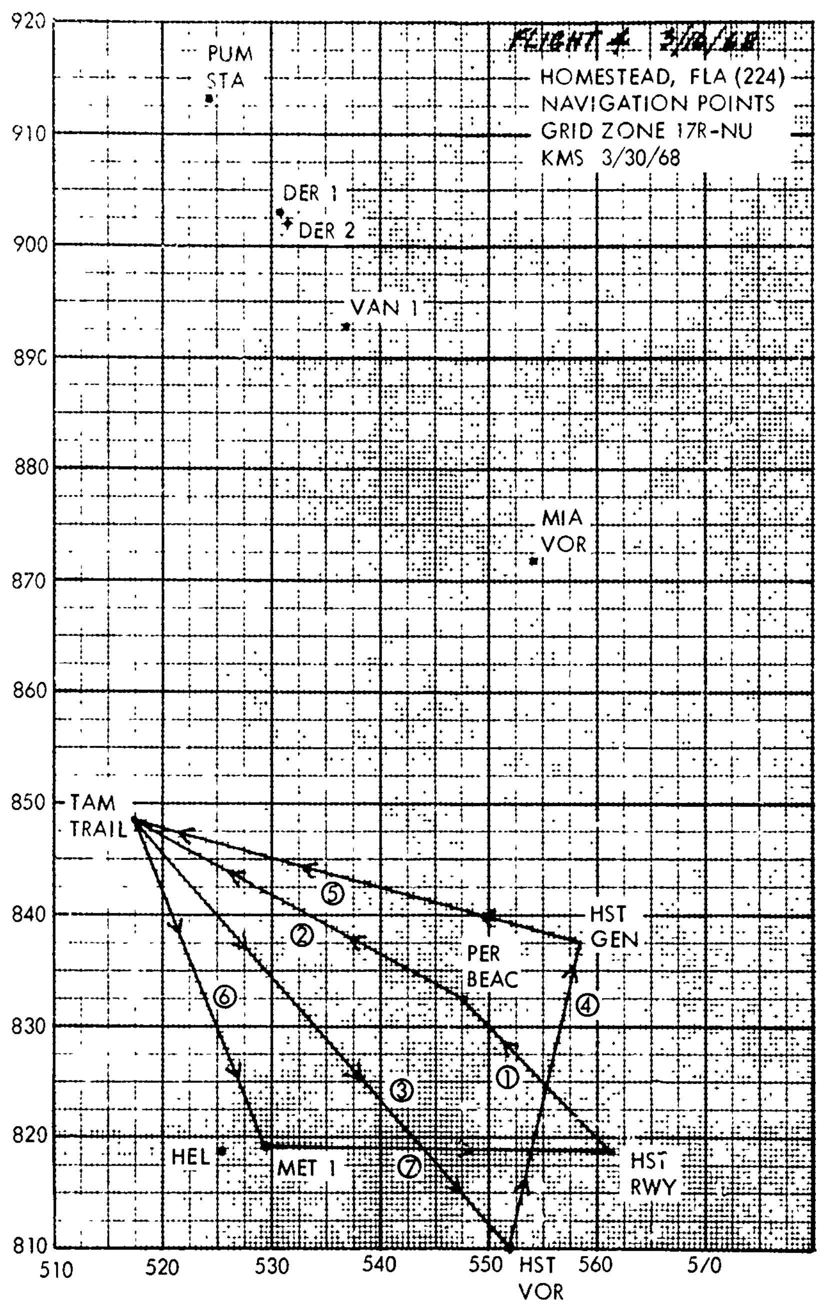


Figure 3-73. Flight 4—J0V1-B (27).

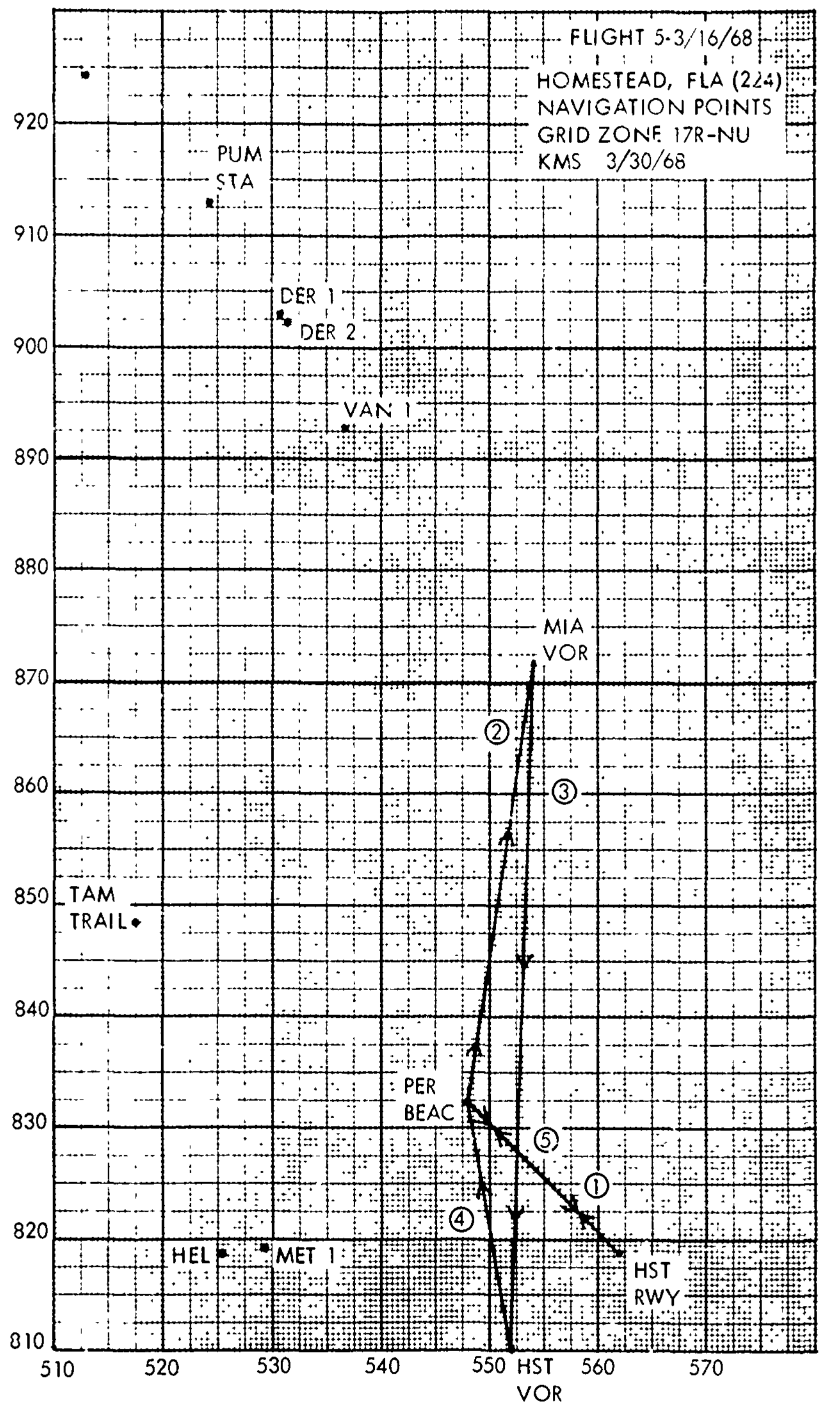


Figure 3-74. Flight 5–J0V1-B (27).

Problem Causes: The navigation cross track error was believed to be due to improper setting of variation to compensate for compass error.

To correct errors in wind calculation at 190 kts, the TAS transmitter control differential synchro was recalibrated at 190 kts.

The turbulence propeller was removed, and the cause of propeller blade loss was not found.

The recorder could not be turned on because the OFF/ON switch on the recorder was left in the OFF position.

This emphasized the need for a preflight checkout procedure. A procedure was written and before every future flight a complete checkout will be conducted.

3.11.3.6 Flight 6/18 Mar 68 (Figure 3-75).

Object: Fly the test grid for pilot observer experience.

Fly a closed navigation course with variation set at 2 degrees West.

Accumulate wind data using the computer digital readout of wind.

Results: The test grid was flown at 50 and 100 feet with no problems being encountered.

The navigation run indicated at the first check point that 2 degrees West variation was incorrect. The variation was changed to 2 degrees East and the data recorded at the next check point indicated that the cross track error still existed. The variation was reset to zero degree for the completion of the navigation run.

Wind data could not be read out digitally because of fluctuations in the digital readout.

Using the VSI wind readout, the wind data indicated that further adjustment of the TAS transmitter control differential synchro was needed.

Problem Causes: Navigation data was not constant enough at one variation setting to determine the compass correction needed. Another navigation flight will be necessary to determine the required variation setting.

Wind inaccuracies were again corrected by readjusting the TAS transmitter control differential transformer for 190 kts.

3.11.3.7 Flight 7/19 Mar 68 (Figure 3-76).

Object: Fly an eight leg closed navigation course at a constant variation of 0.4 degree East to gather data from which the adjustment to variation due to compass error can be computed.

Gather wind data at 190 kts.

Results: Navigation data indicated that the compass correction should be an additional 3.6 degrees East variation. All future flights will be flown with the variation set at 4.0 degrees E.

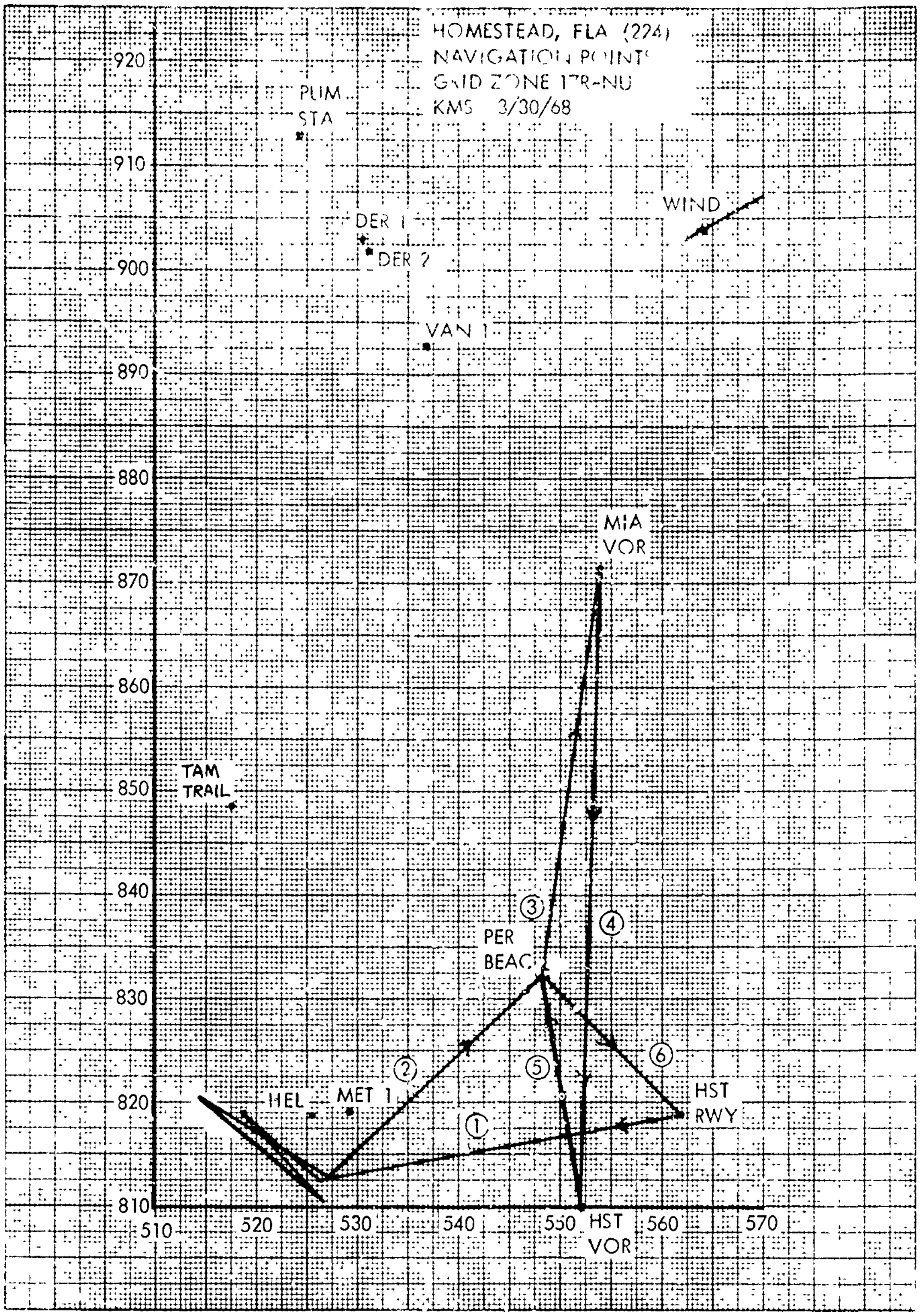


Figure 3-75. Flight 6—30V1-B (27).

Wind data indicated that the correct setting of the control differential synchro had been found.

3.11.3.8 Flight 8 (20 Mar 68 (Figure 3-77).

Object: Fly a closed navigation course to ensure that the variation setting of 4.0 degrees East is correct.

Fly without a turbulence propeller, and create a turbulence of 0.5 by using the calibrate mode in the MRI.

Fly over the grid at 100 feet in a North-South pattern with 2-KM separation between 20-KM legs.

Try to obtain detections of meteorological station 1 with math model 3.

Results: Navigation accuracy indicated that the compass correction of 3.6 degrees East plus the area variation of 0.4 degree East are correct and minimize navigator cross track error.

The system was fully operational throughout the entire flight.

The grid flight produced many offsets and marks, in the correct direction and mostly indicative of C/N. The background was about 20,000 particles/cc, and evaluation of the recorder tape is necessary to determine if detections were made.

3.11.3.9 Flight 9/21 Mar 68 (Figures 3-79 and 3-80).

Object: Fly a closed navigation course to ensure proper navigator operation.

Fly the grid at 100 feet to obtain detections of meteorological station 1.

Results: Navigation run indicated proper navigator operation and minimum cross track error.

After navigation run, the recorder stopped running, this disabled the computer and no plots or recording could be made of the grid run. Aircraft returned to Homestead AFB without flying the grid.

Problem Causes: The recorder malfunction was caused by a failure of the recorder tape cartridge to engage all of its interlocks.

The interlocks were jumpered out of the recorder to prevent a reoccurrence of this problem.

3.11.3.10 Flight 10/21 Mar 68 (Figures 3-81 through 3-84).

Object: Fly North of the AFB to the Miami canal and ensure that map boards can be interchanged without losing plotter/navigator synchronization.

Fly along the down-wind side of the canal at 100 feet, and attempt to make C/N detections of the derricks located in the canal.

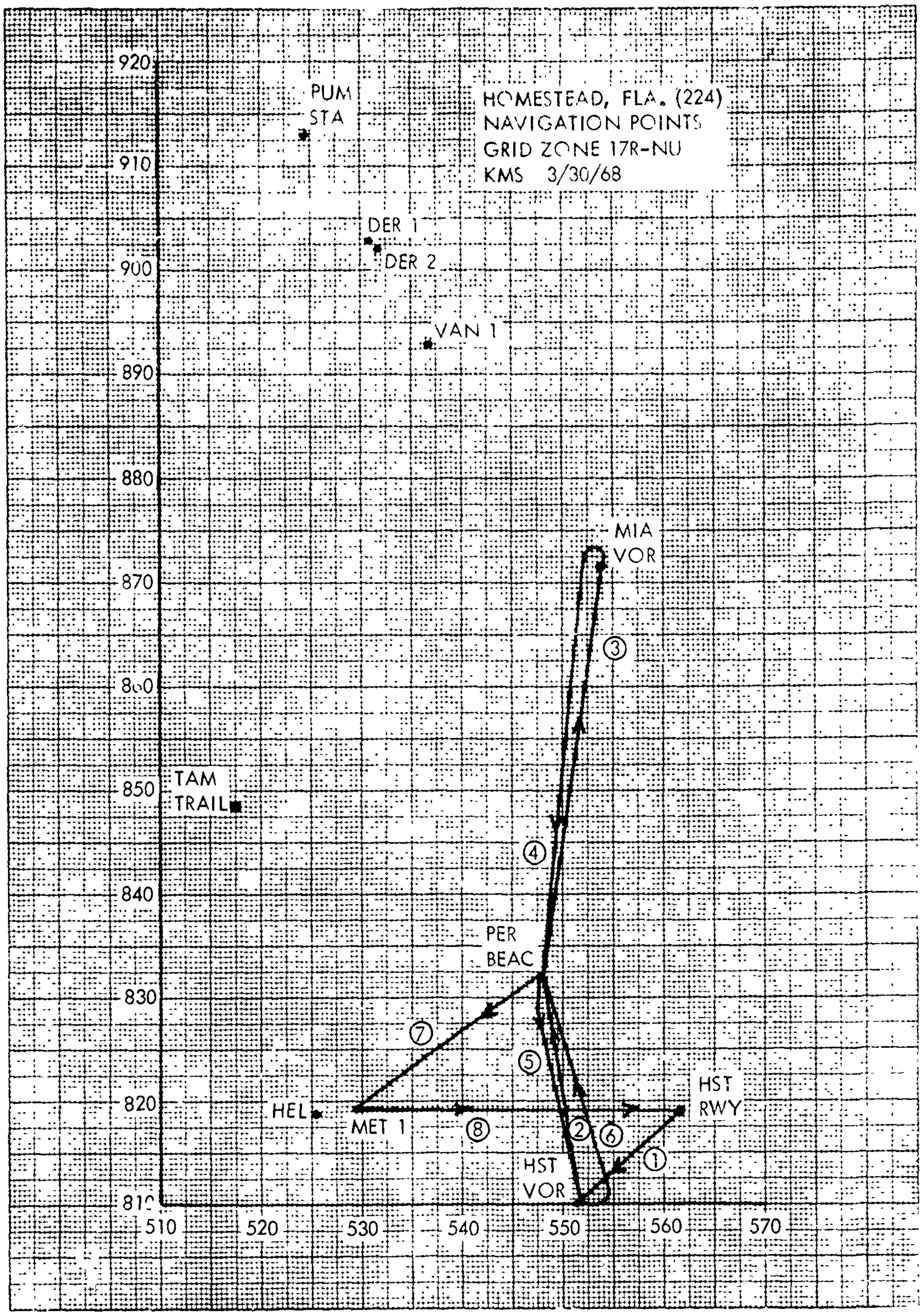


Figure 3-76. Flight 7—J0V1-B (27).

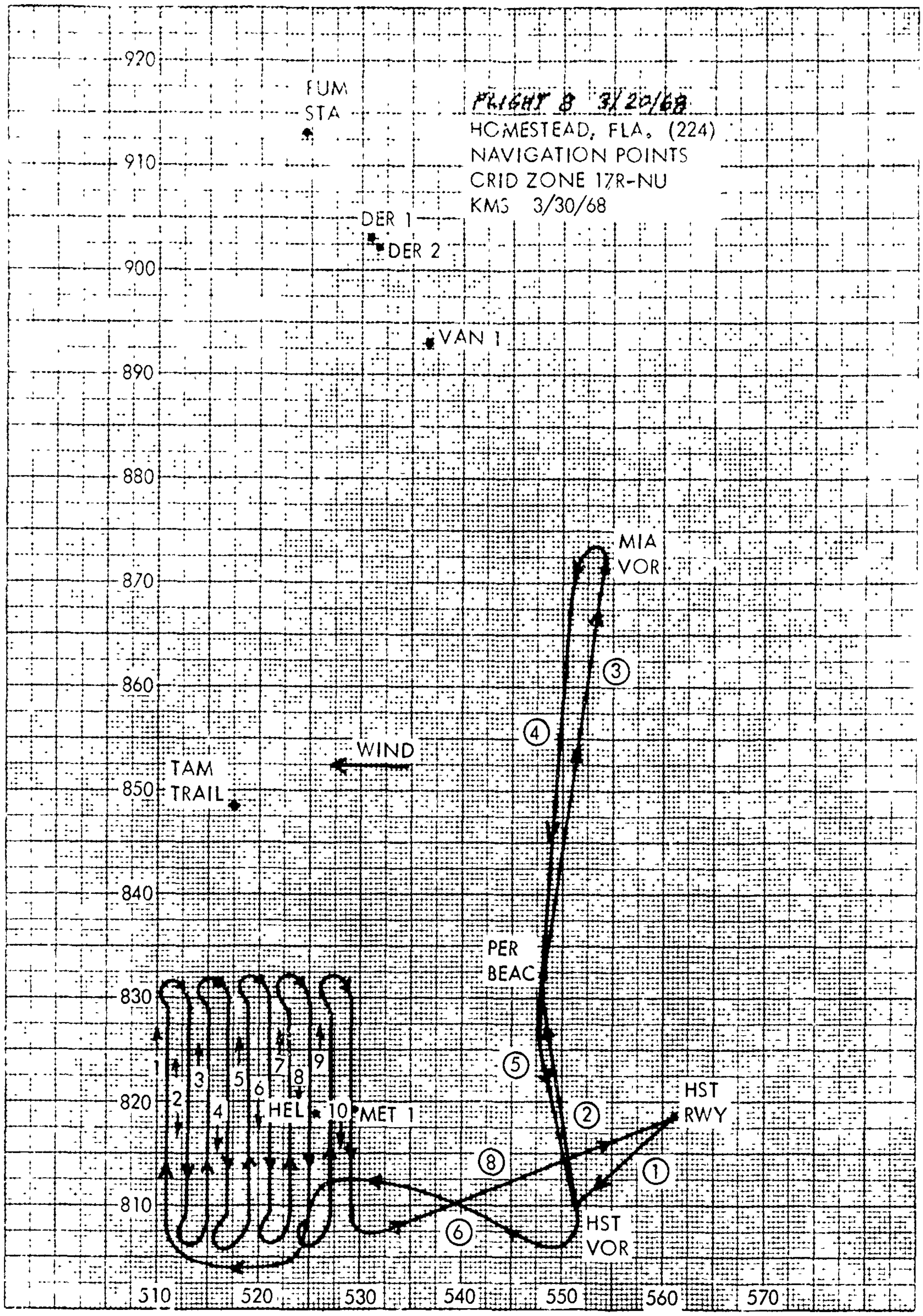


Figure 3-77. Flight 8—J0V1-B (27).

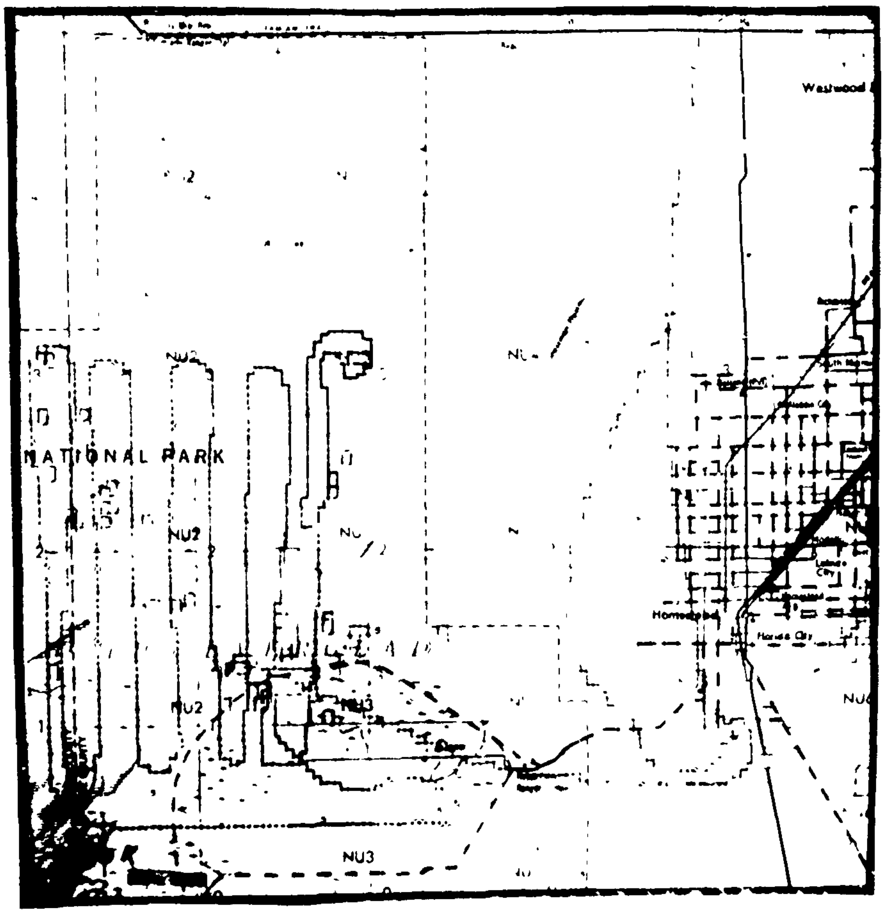


Figure 3-78. Flight 8—J0V1-B (27) (MAP).

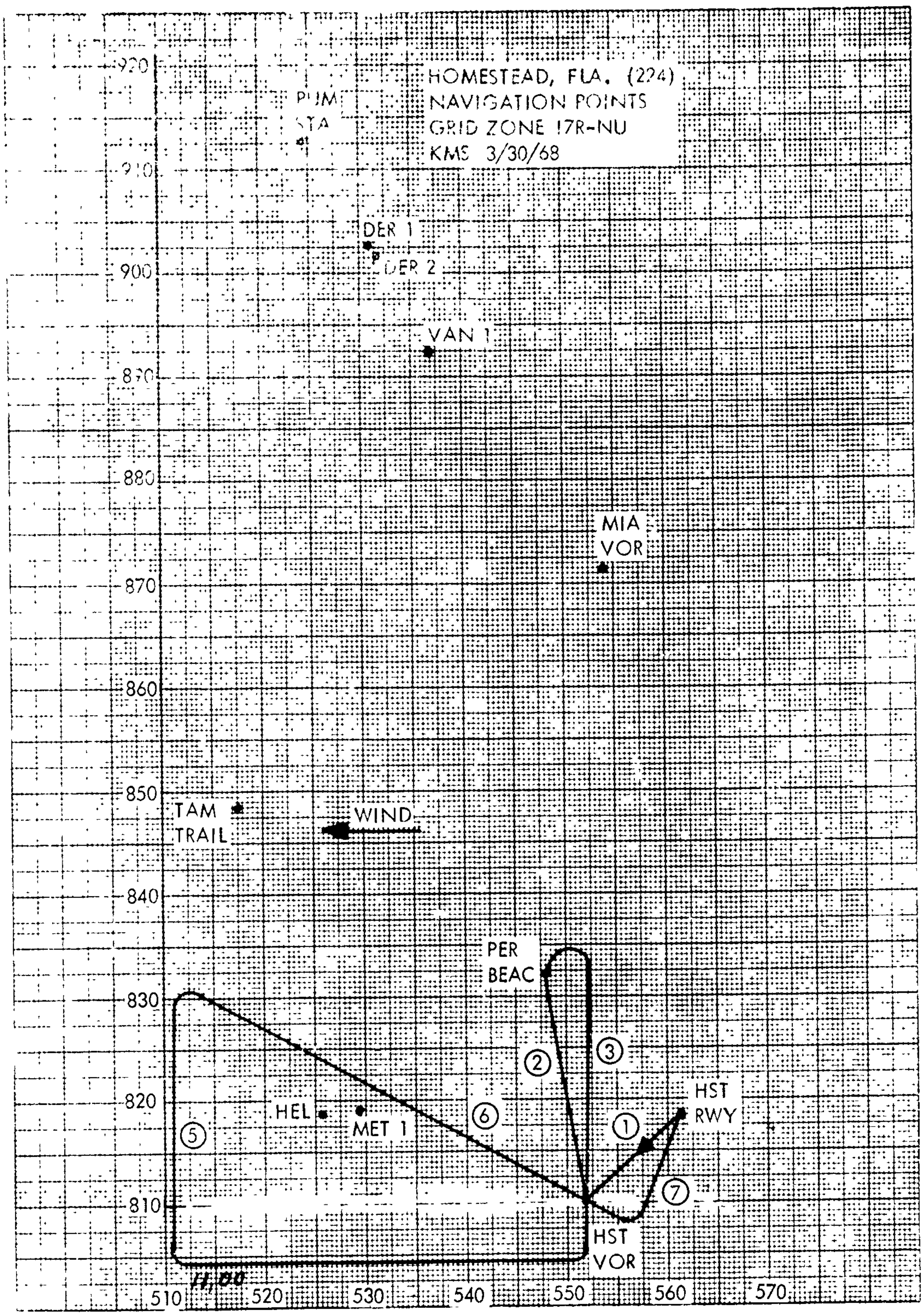


Figure 3-79. Flight 9—J0V1-B (27) Navigation Points.

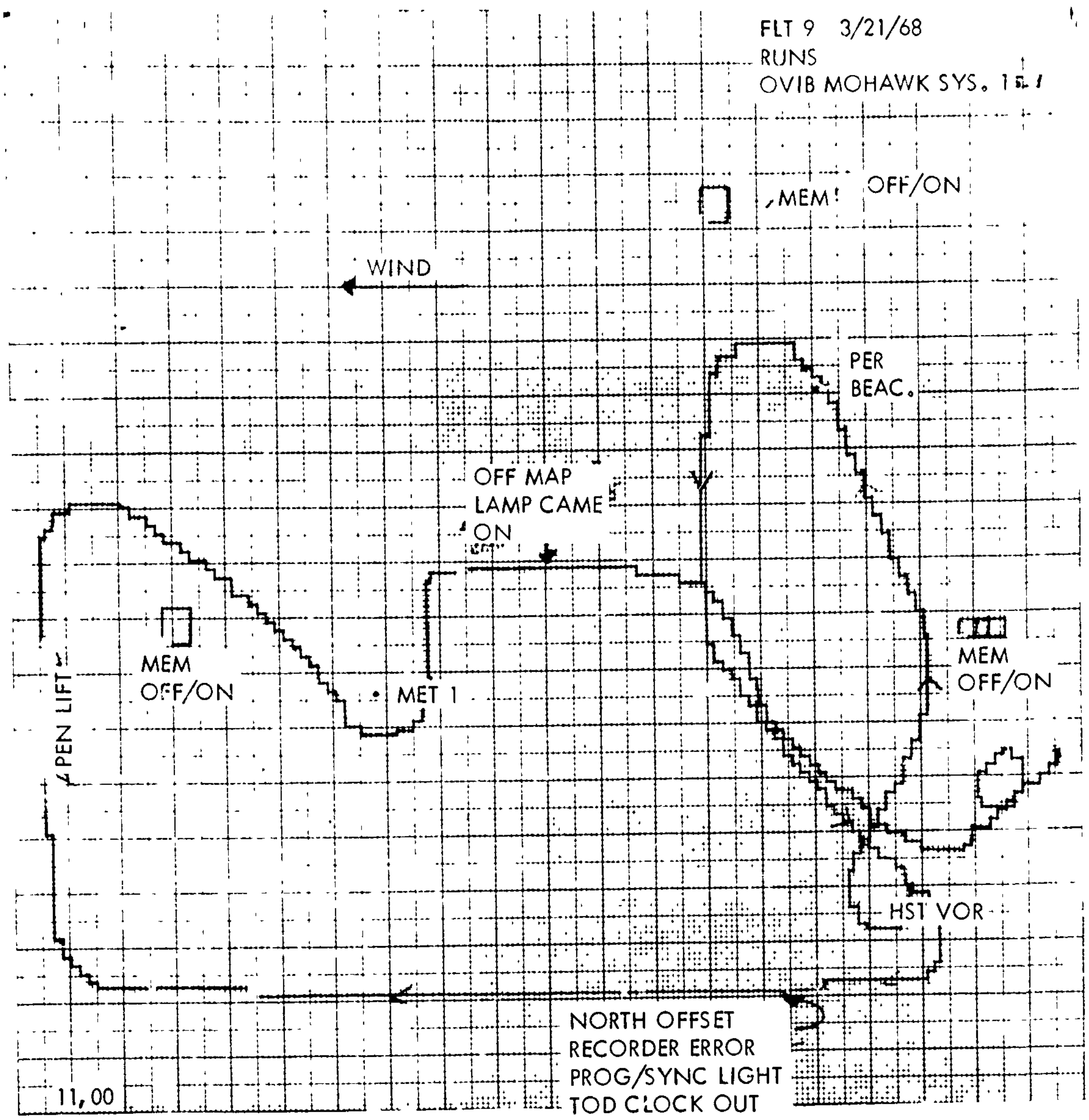


Figure 3-80. Flight 9—JOV1-B (27).

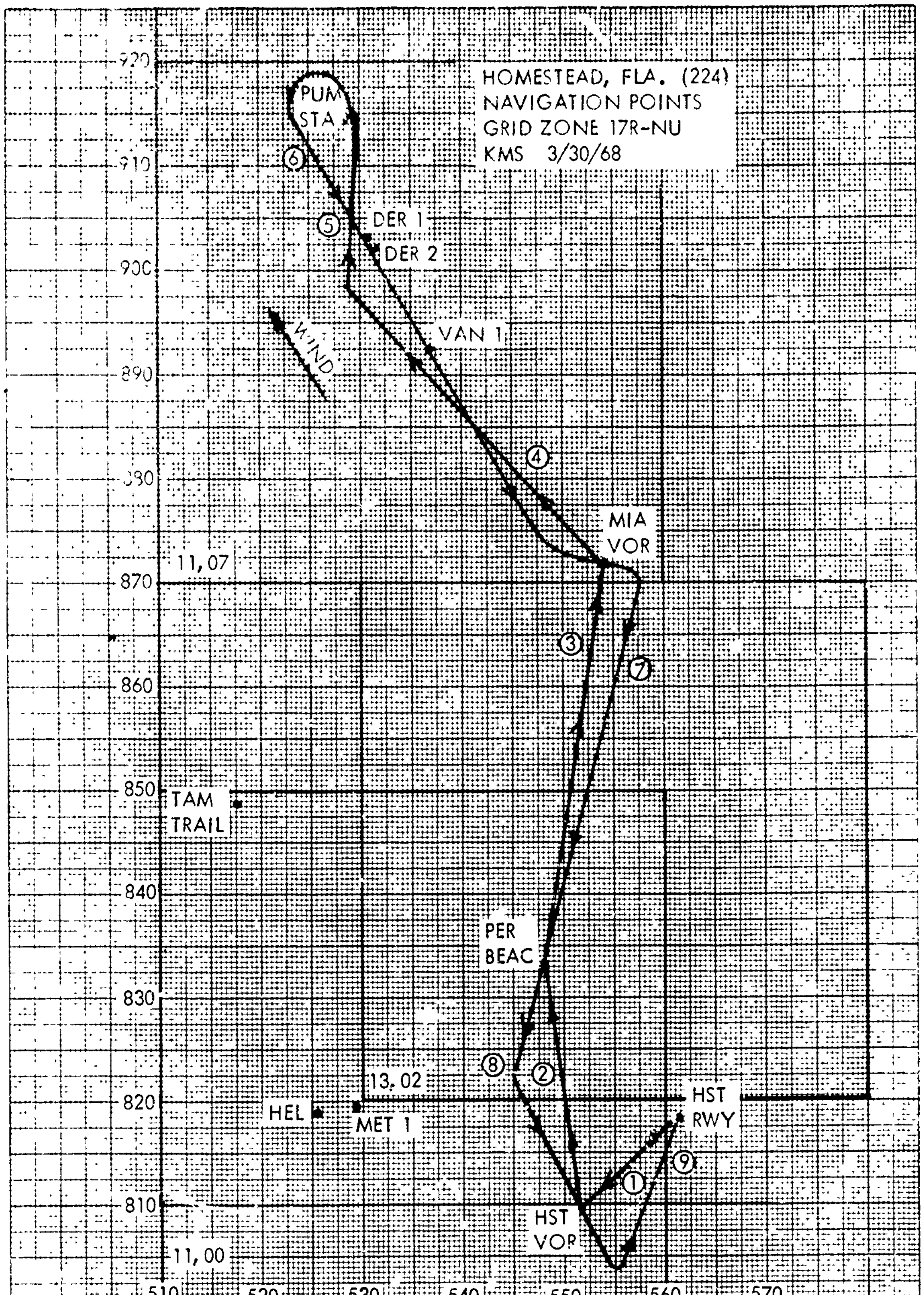


Figure 3-81. Flight 10—J0V1-B (27).

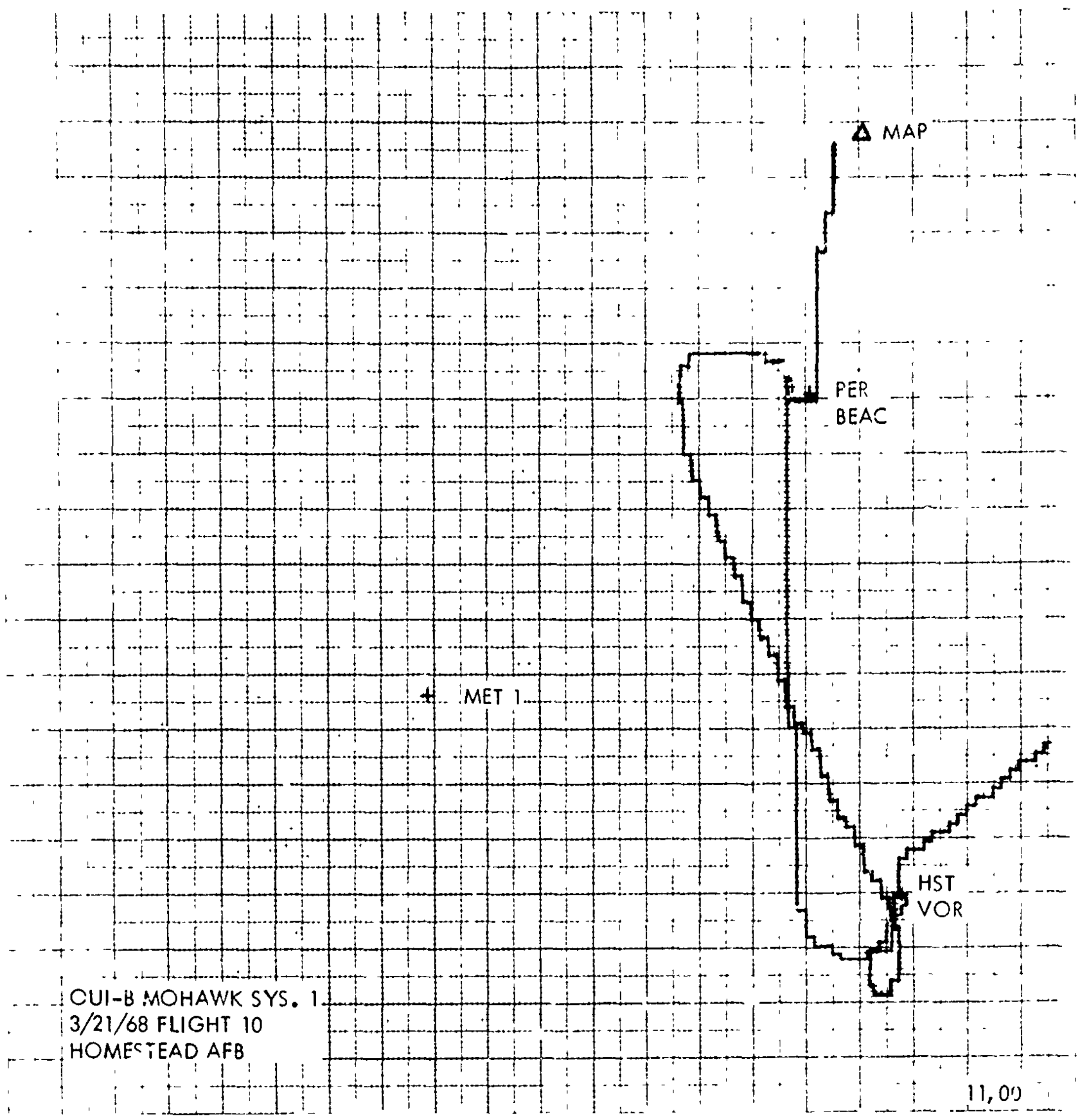


Figure 3-82. Flight 10--J0V1-B (27).

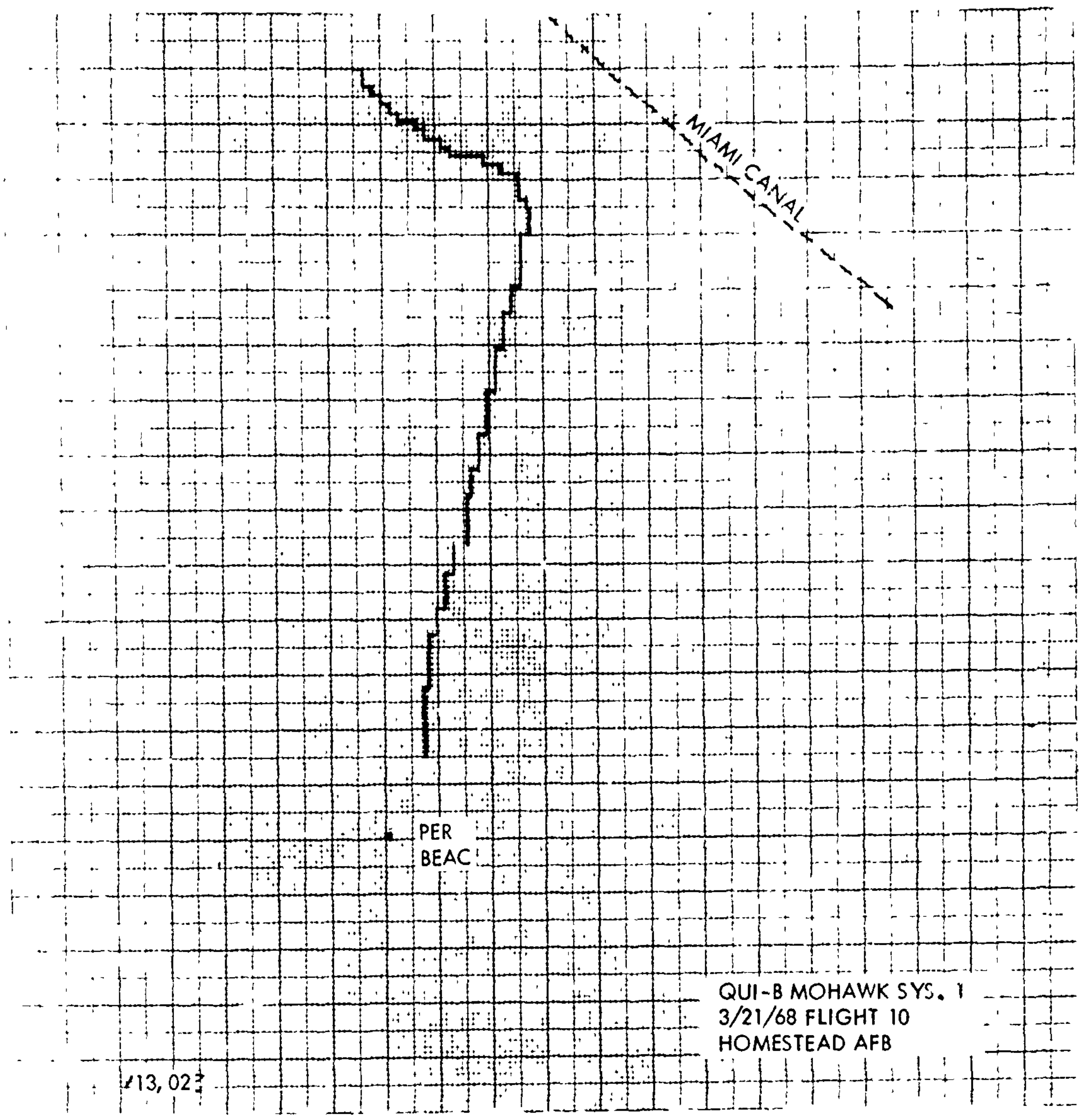


Figure 3-83. Flight 10—J0V1-B (27).

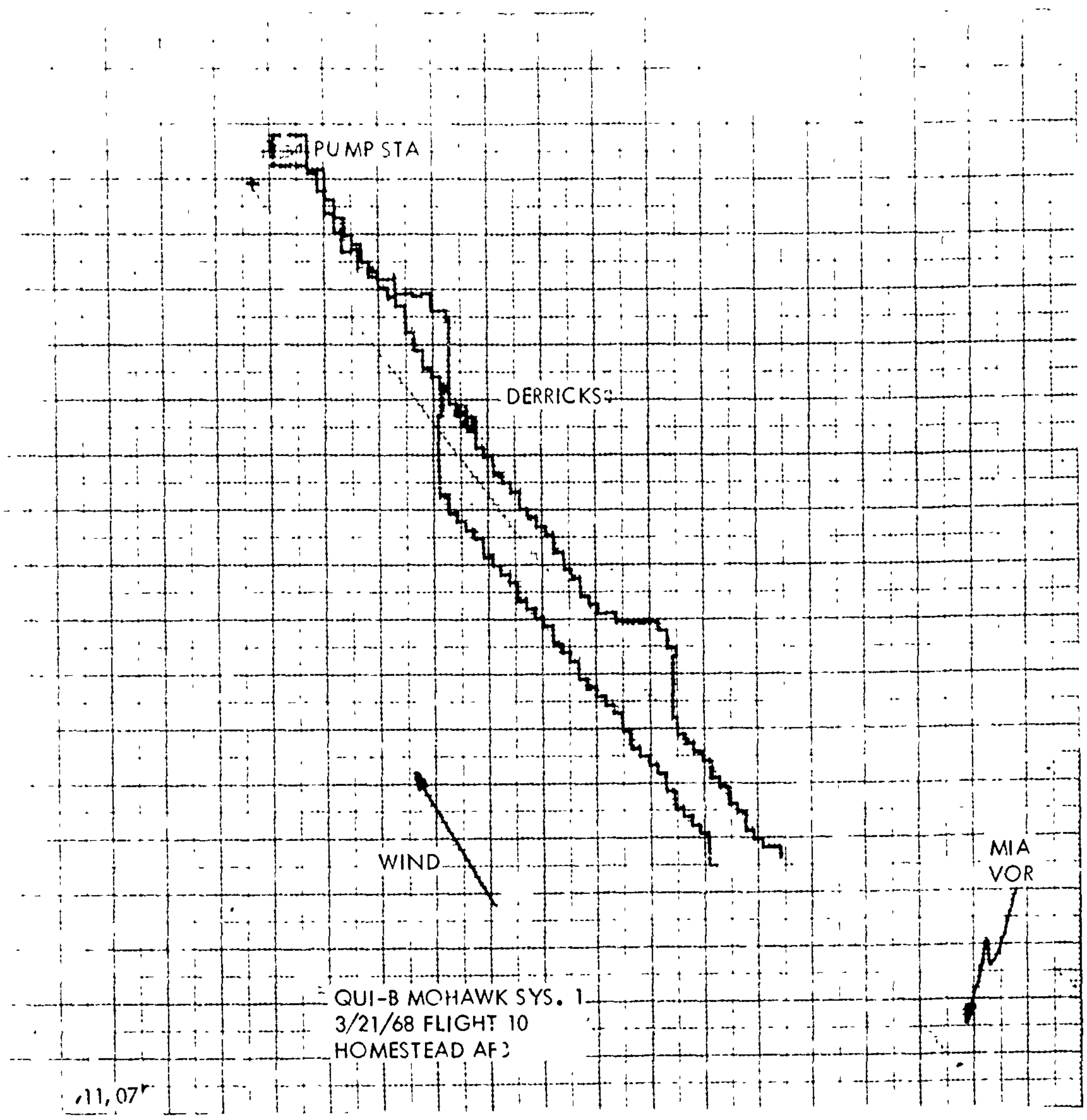


Figure 3-84. Flight 10--J0V1-B (27).

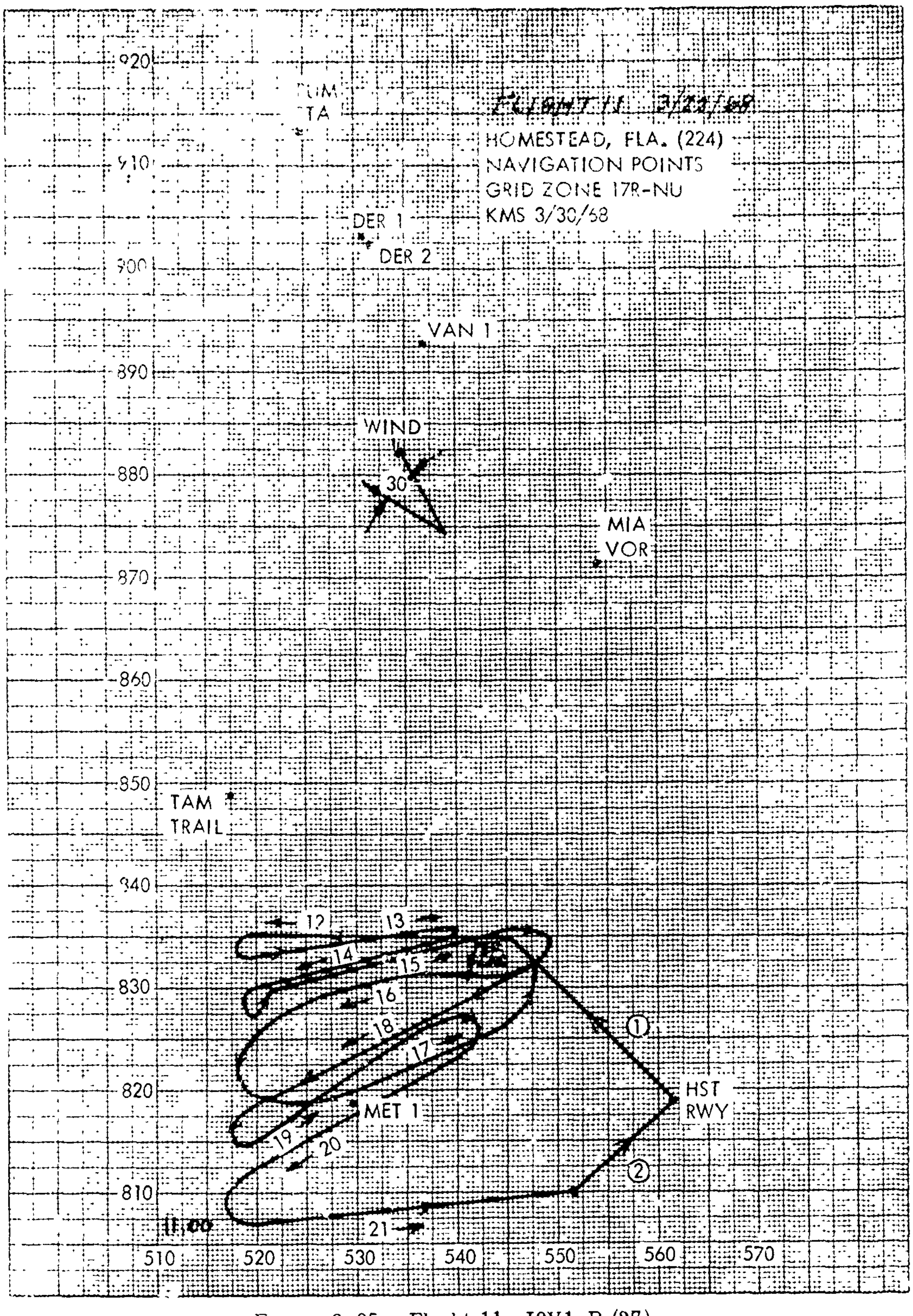


Figure 3-85. Flight 11—J0V1-B (27)

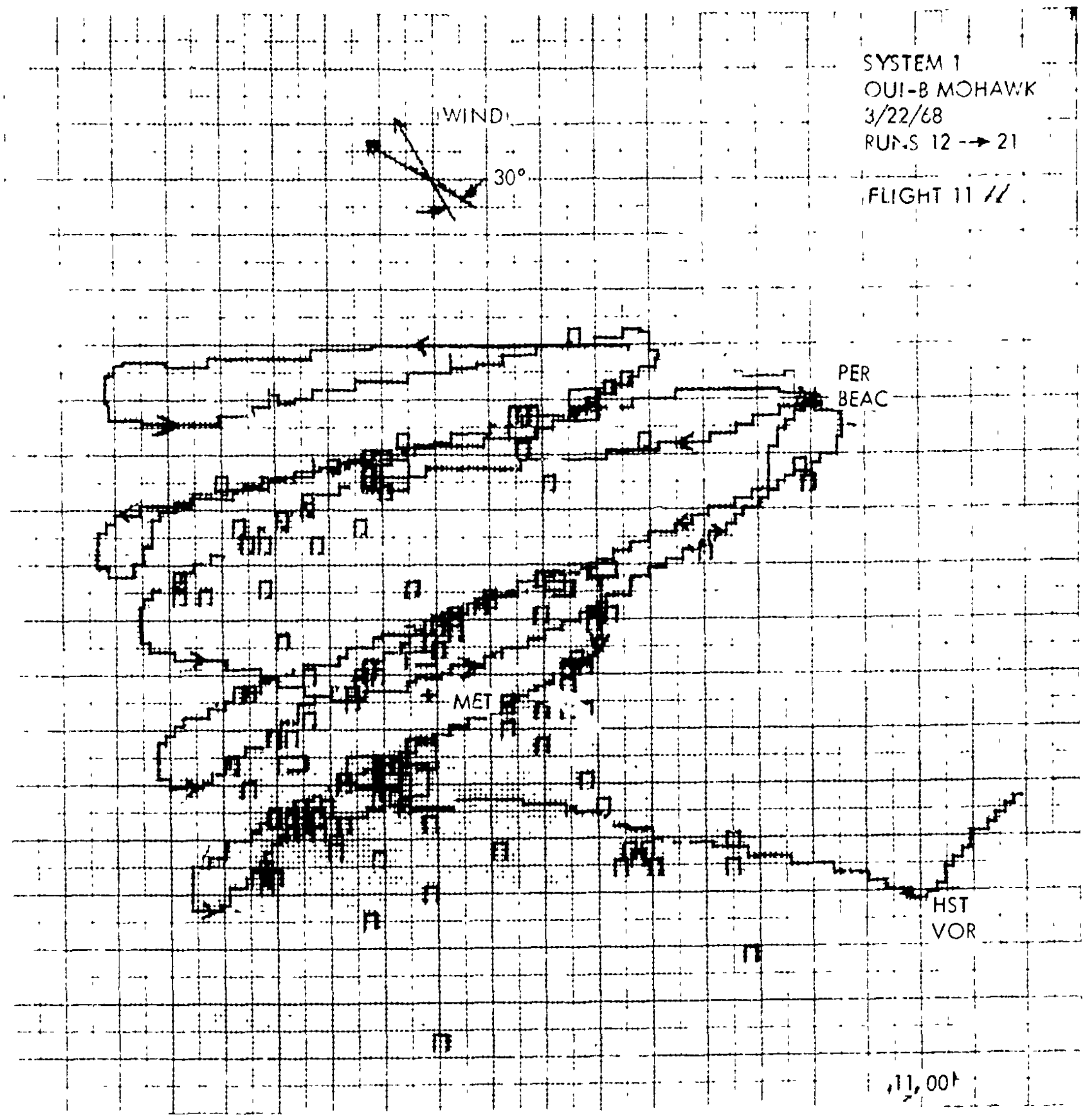


Figure 3-86. Flight 11—J0V1 3 (27).

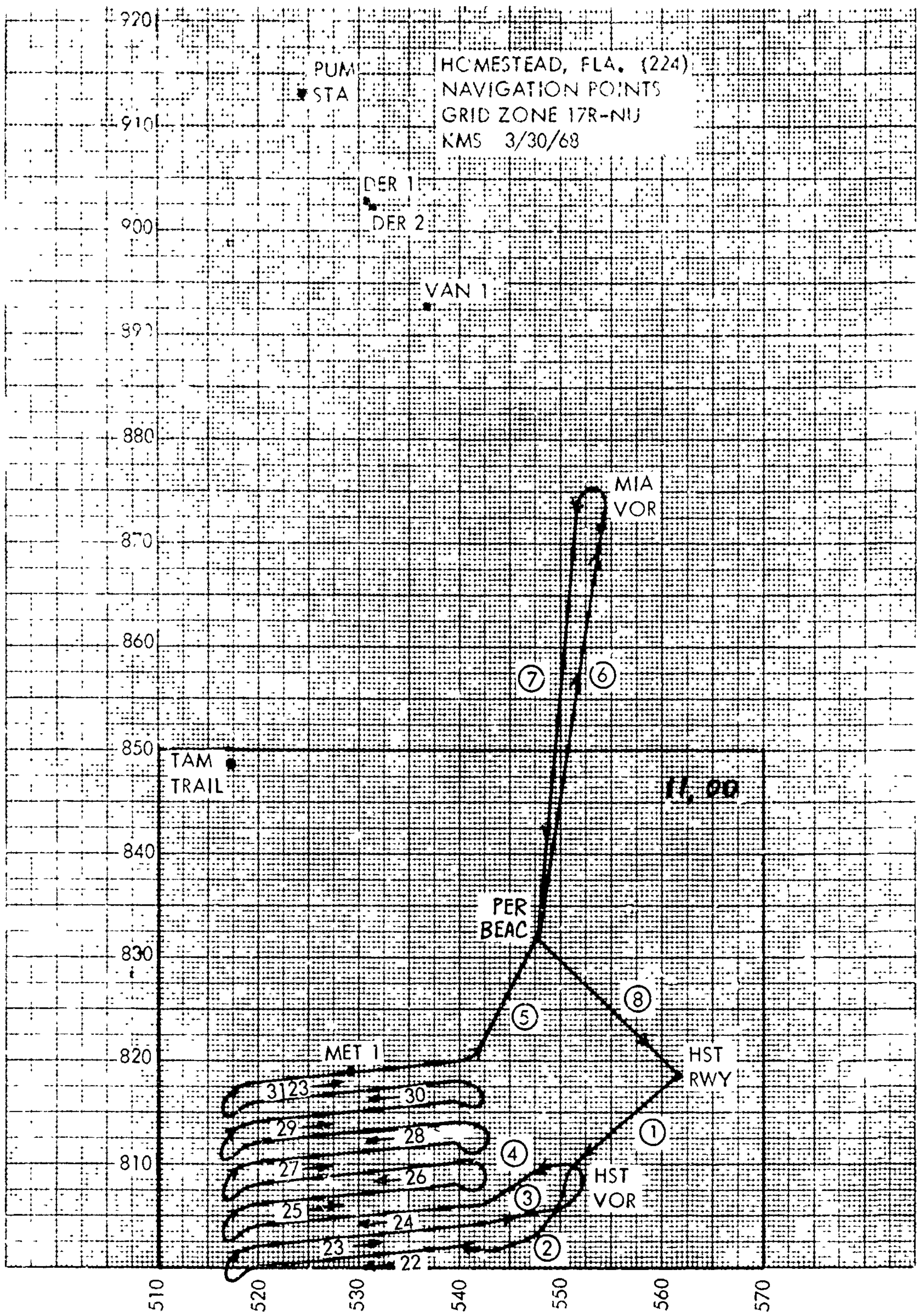


Figure 3-87. Flight 12—J0V1-B (27).

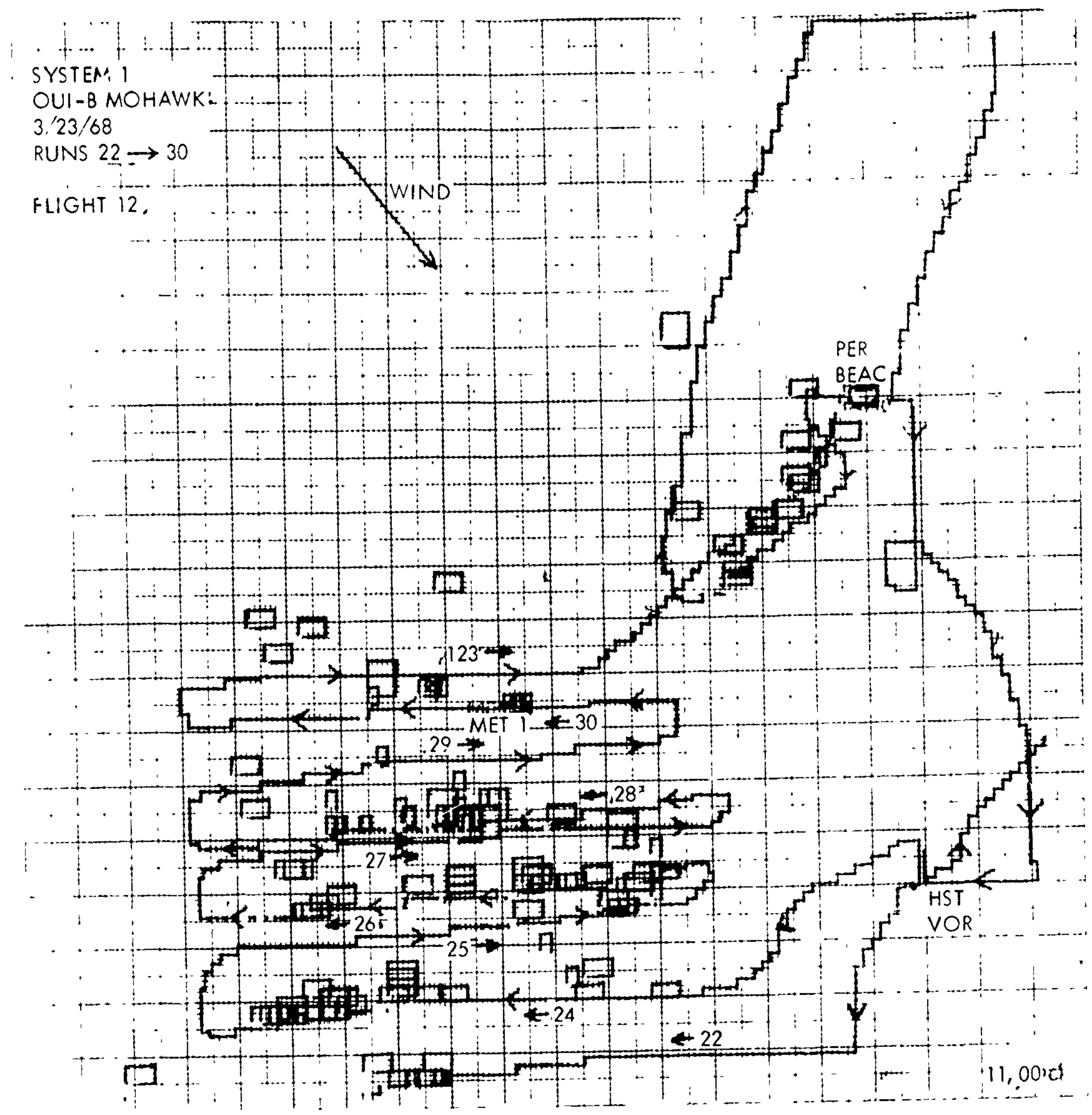


Figure 3-88. Flight 12—J0V1-B (27).

Locate the pumping station in the canal and using it as a starting point fly directly over the canal and pinpoint the exact map coordinates of the pumping station and the derricks.

Results: Immediately after takeoff, a malfunction occurred in the analyzer. The range switch for Channel 2 became stuck between the 5K and 20K range. In this condition, the Channel 2 range switch draws a current of 4 amperes and heats up rapidly. The analyzer was shut off so that Channels 1 and 3 could be used when the detection run was in progress at the canal.

The flight involved using three overlapping map boards with map index numbers 11, 00/13, 02/11, 07. No problems were encountered in going from one map to another.

Upon reaching the canal, the flight was altered and the aircraft flew along the canal and to the south of it. When the region of the canal derricks was reached, the analyzer was turned on. No C/N detections were evident on the plotter, and the computer data light was continually on.

The wind was checked and found to be parallel to the canal, thus preventing any detections. The course was altered when the derricks were in sight so as to place the wind as close to perpendicular to the flight path as possible. No detections of C/N were plotted, although it was evident that the detector output increased during this run. Due to the condition of the analyzer, power was removed from it.

The pumping station, two derrick locations, and a workman's van were flown over at 100 feet and their locations were recorded.

Problem Causes: The analyzer malfunction was due to a failure in the automatic range switch reset. This problem has occurred previously, and appears to be a problem in the switch. The conditions under which the malfunction may occur are:

1. AUTO RANGE Mode.

2. Switching from 5K to 20K scale under most conditions the hangup can be corrected by going from AUTO to MANUAL, range mode and depressing the INC pushbutton, to reset the switch.

The recorder was fully operational throughout the flight and analysis of the recorded data is necessary to determine if any detections were made, and not plotted.

3.11.3.11 Flight 11/22 Mar 68 (Figures 3-85 and 3-86).

Object: Fly the test grid with a threshold of 1.5, math model 3, and a fixed turbulence of 0.5+. Attempt to make detections of meteorological station 1 and a (C/N) source located to the S/W of the meteorological station.

Results: The initial run on the grid indicated that the wind had shifted and a change in the grid pattern was necessary. The grid pattern was shifted as shown on the map. This created some problems between observer and the pilot.

During the flight, many offset marks were made. This data must still be analyzed with data reduction.

All equipment was fully operational throughout the flight.

3.11.3.12 Flight 12/23 Mar 68 (Figures 3-87 and 3-88).

Object: Fly the test grid with a threshold of 2.5, math model 3, and a fixed turbulence of 0.5+. Attempt to make detections of meteorological station 1 and a C/N source located to the S/W of the meteorological station.

Fly a navigation run to check navigator accuracy in DG mode.

Results: The initial run on the grid indicated that the wind had shifted. The grid pattern was shifted as shown on the map without creating any problems between the pilot and observer.

During the flight many offset marks were made; however, detector No. 3 (C/N) appeared to be insensitive and detector No. 1 appeared to be in saturation.

The plotter was allowed to go off the 11, 00 map. When flight path again corresponded to 11, 00 map coordinates, the plotter began plotting once again.

All equipment, other than the detectors mentioned, appeared to function normally throughout the flight.

During the flight, many offset marks were made. This data must still be analyzed with data reduction.

The navigation run in DG mode indicated considerable error in the E/W direction.

Problem Causes: The detectors for Channels 1 and 2 appeared to be considerably out of calibration.

3.11.4 Second Field Test Series

The second AMPD-224 System 1 field testing series was conducted at Homestead Air Force Base, Homestead, Florida starting 2 Jul 68. The objective of this series of flight tests was to demonstrate the accuracy of source prediction of an AMPD system for a point source of ON particles, to be done by using a UH-1 helicopter as the CN source at a test site in the Everglades National Park. A secondary objective was to demonstrate the operability of the 0V-1 system.

Meteorological conditions were generally not favorable for testing. Record rainfalls were being recorded in the area. Winds were usually light, under 10 knots, and very low in the the morning; when they picked up later in the day, thunderstorms would form over the test area. Wind direction was typically SE or S, which was favorable, because it resulted in a very low CN background of less than 1000 particles/cc. Temperatures reached into the 90's most days. with high humidity.

The UH-1 helicopter arrived at Homestead on 12 Jun 68. It was used during the next two days to select eight landmarks in the grid area for use as navigation update points, and to place parachute markers where needed for update point identification.

Due to a variety of problems with the equipment, the aircraft, the weather, and digital readout programs at the University of Miami, successful flights were not achieved on the test grid.

Flights were made that demonstrated navigation accuracy and recorded wind calibration data. It was considered that a successful wind calibration was achieved based on VSI data.

Many of the equipment problems were self-induced, and would be prevented with more experience in keeping the system operational in the field. When the aircraft left for Aberdeen. the only unsolved problem that prevented data flights was a cabling fault involving the turbulence signal.

3.11.4.1 <u>OV-1 Equipment Problems/Uncorrected.</u>

1. Documentation of equipment and cabling was not available with the aircraft to permit successful maintenance of the system.
2. The computer program did not control the DIS CON display properly in the east coordinate.
3. The plotter slew switch did not operate correctly with the navigator.
4. The wire for turbulence output appeared to be shorted to ground.
5. The spare recorder hand carried to Homestead would not operate in the aircraft.
6. Some detectors require 10 to 15 minutes of running before they operate correctly.

3.11.4.2 <u>OV-1 Equipment Problems/Corrected.</u>

1. A pinched wire in the turbulence input cable shorted the MRI power supply to ground and burned out the supply. The MRI electronics unit was replaced with a spare shipped from Aberdeen.
2. The turbulence sensor shaft bearings failed and the shaft assembly was replaced with a spare shipped from Pittsfield.
3. The turbulence sensor shaft spinner was lost in flight due to a missing lock nut and was replaced.
4. A turbulence propellor was damaged and replaced.
5. The turbulence and ground wires were broken at the connector to the MRI unit.
6. The computer program entered an endless loop for all alarms and could not generate any offset plots.
7. The computer test plot routine operated improperly.
8. A computer memory unit failed and was replaced with the unit from the C-47.
9. The magnetic tape print out problems on the IBM 7044 computer at the University of Miami were solved by first reading and rewriting the tapes on an IBM 1401 machine. This was first throught to be a recorder problem.
10. A potential heat problem in the recorder was solved by replacing the fan.

11. The fan replacement above caused a recorder problem when the wires to the fan were not properly reconnected.

12. An internal recorder connector vibrated loose in flight when not properly clipped in place.

13. A recorder electronic failure in the record gap circuitry was repaired. This required a readjustment of the gap spacing circuits.

14. A fuze was blown in the navigator when an attempt was made to use the doppler simulator. This probably occurred when power was not switched on in proper sequence with the added load of the simulator.

15. The control indicator in the navigator did not generate distance to destination signals properly on the VSI and was replaced.

16. The compass controller did not slew the compass properly and was replaced and repaired.

17. The yaw heater was not disconnected from detector fan power when the aircraft arrived.

18. A detector range switching circuit board failed and was replaced.

3.11.4.3 Suggested Design Improvements. Suggested design improvements based on flight test experience follow.

1. Tubing to the pitot tube should have a high point so that water cannot be trapped.

2. The temperature probe cable should be restrained so that it cannot foul when the pod nose is removed.

3. The output connector on the MRI unit should be replaced with a quick disconnect type.

4. Cables and connectors that are disconnected when the pod ends are removed should be restrained so they do not foul when the ends are slid off.

5. Pens are fragile and must be considered an expendable item.

6. A pitot tube cover should be provided.

7. A cover and shorting plugs should be provided for the Mk 12 Computer.

8. The navigator should be modified to display ground track on the VSI in the wind read and set modes.

9. Improved signal detection and analysis techniques must be developed.

10. A better strain relief is required for the wing cables.

11. The digital recorder appears to have a temperature design problem that should be analyzed.

3.12 FIELD TEST—SYSTEM 2

The second system was shipped to Westover AFB and only three and a half days were allowed for UH-1D installation and checkout. Therefore, field testing, and installation checkout were conducted more or less together at Homestead AFB during the period from March 14 to March 24, 1968

Following compass swing at Fort Rucker on March 11 and March 12, the UH-1D was flown to Homestead AFB. From March 14 to March 18 while helicopter maintenance was being performed, some system checkout was accomplished.

The systems power control was rewired to take its excitation from the non-essential power bus The side-slip potentiometer was rewired so that the slip angle could be read on the system test panels meter. However, the side-slip sensor was left disconnected during all flights because the sensor was not in clean air. The true airspeed correction was recalibrated for 75 knots. The Navigator developed lock-on problems caused by water in the radome and the wiring of the true airspeed correction synchro. A defective test switch on the system test panel was replaced. The Channel 1 detector did not have any output. It was replaced by a spare.

The analyzer's channel one level detector was defective and the spare modules were found to be out of calibration. The calibration procedure for these modules requires special equipment which was not available. Calibrated modules were sent by the Circuits engineering which operated satisfactorily. The channel three automatic reset for the switch had excessive delay which was not correctable in the field. Also the audio transformer used to connect into the ICS burned out when excessive audio power was applied to it.

A new recorder was hand carried to Homestead, bench-tested, and mounted in the helicopter.

A major problem was the female side of the pylon connectors. Metal chips in a number of the pin sockets prevented locking the pin in place. As a result, the pins would push back and lose contact. Considerable time was spent attempting to clear the chips out of the sockets so that the pins could be successfully locked in place. This problem was encountered in the lab when first wiring the pylon connector; at Westover AFB when installing the system on the helicopter, and at Homestead AFB.

3.12.1 Navigator Check Flight

On March 19, a navigator check flight was made and it was found that 0.4 degree variation was needed to correct for the noted error.

Detector No. 3 appeared to be noisy during most of the flight although all three detectors tracked very closely on the ground. The altimeter and ground speed readings seemed to be high. Also the wind solution would sometimes drift and seemed to be at the wrong angle otherwise.

The tape recorder error light came on after three minutes, and it was impossible to ready any of the tape on the 415 computer.

On the next day, the skid next to the navigator's antenna was covered with Eccosorb. The navigator was realigned and the true airspeed correction synchro was rewired and realigned.

This step was an attempt to improve lock on and wind solutions. The tape recorder was removed to be repaired. During the afternoon of March 20 and March 21, the UH-1D was used to transport personnel to the test site.

3.12.2 Flight 22 Mar 68

A flight was made on March 22 (see figure 3-89 and para 3.12.2.1 data sheet for tests 501-508) and it was found that detector No. 3 was still noisy, so its computer disable was left on during the mission. The groundspeed and altimeter problem seemed to be solved.

The tape recorder failed again without recording any meaningful information.

3.12.2.1 Data Sheet/Tests 501-508

Reported Wind--145 deg 15 Knots

Planned Flight Path/22 Mar 68

	Planned N	Planned E	Nav Reading N	Nav Reading E	
Home	818.5	581.3			
HSO-VOR	809.5	551.6	811.2	558.2	Update
N.C.	811.6	549.4	812.6	549.0	
Perine	832.5	547.5	832.7	551.0	Update incorrect
	825.0	524.0			
	825.0	532.0			
Run 3 E/W	823.0	524.0			
Run 4	823.0	532.0			
Run 5	821.0	524.0	821.4	524.4	
Run 6	821.0	532.0			
Run 7	820.0	524.0			
Not Used	820.0	532.0			
	819.0	524.0			
	819.0	532.0			
Run 8 N.C.	810.6	549.0	810.5	549.4	
Home	818.5	561.3			
Met 1			819.4	529.3	Approximately 1/2 km N of targets
Heli			819.4	527.0	
Met 1			819.2	529.4	Over targets
Heli			819.7	526.2	
HSO-VOR	809.5	551.6	811.2	556.2	

Wind Readings

180 deg at 20 knots
185 deg at 31
150 deg at 20
180 deg at 12
160 deg at 10
180 deg at 20
180 deg at 10
145 deg at 15—Met 1—145 deg at 15

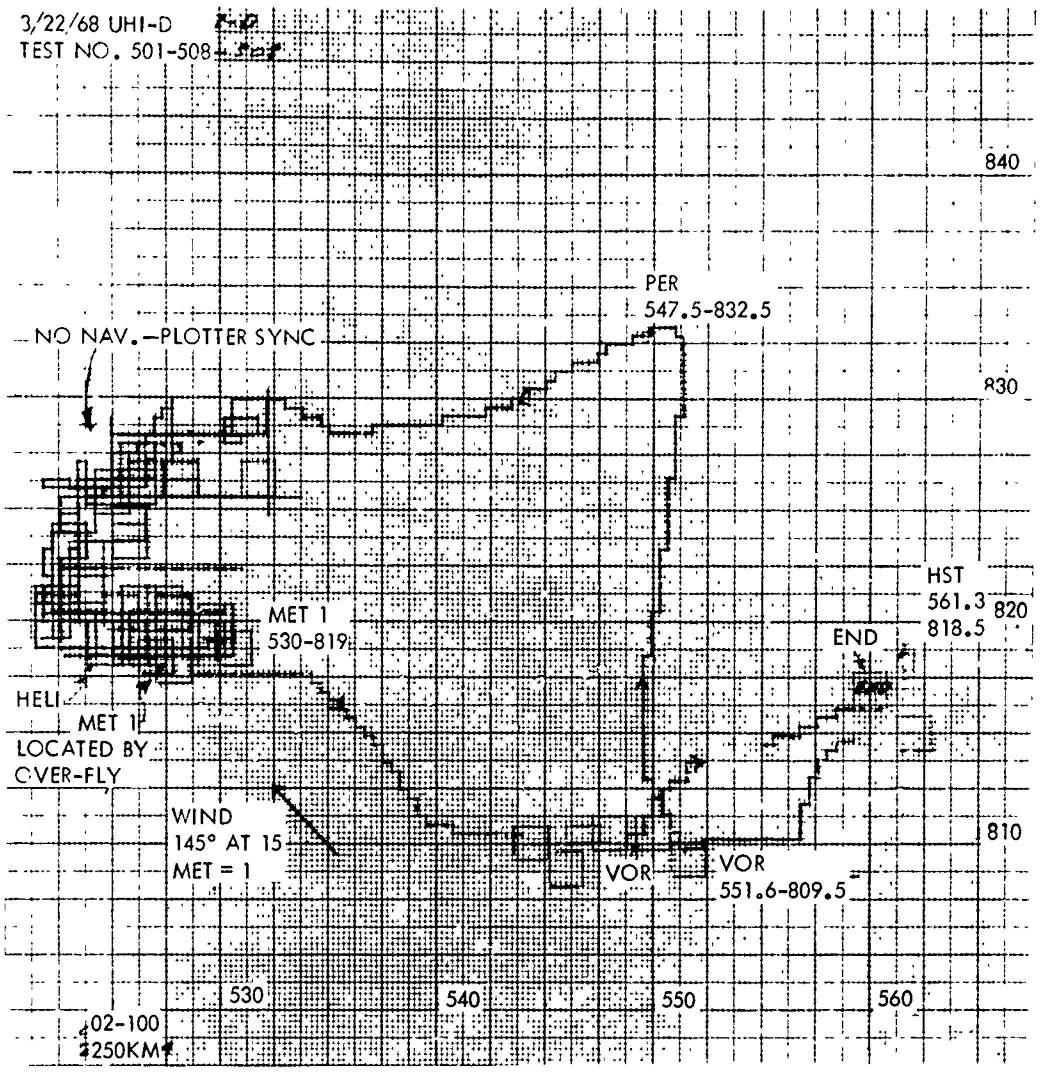


Figure 3-89. Tests 501 through 508 UH1D (89).

3.12.3 Flights 23 Mar 68/24 Mar 68

A flight was made on March 23 without the tape recorder. An OV-1 detector was used for Channel 3, although it was reading considerably lower than the other detectors. The analyzer's Channel 3 range switch would sometimes malfunction when on automatic. Therefore, the switch was left in manual for the flight.

The plotter's pen clogged on the way out to Met No. 1, so no useful plot was obtained of the mission. The time-of-day reset for some unknown reason. This was the only malfunction of the time-of-day observed while in Florida. (See figures 3-90 and 3-91 and para 3.12.3.1 data sheet.)

On March 24, the tape recorder appeared to be operating properly on the bench while being jarred. It was then installed on the helicopter. The helicopter was then started and run for several minutes. Fifteen minutes of tape were used while the helicopter was running without receiving an error signal. However, the tape recorder failed the next time that it was checked on the ground. The tape was not checked at that time to see if any information could be read.

The major problem with System 2 mounted on the UH-1D was the continuing tape recorder failure caused by the helicopter vibrations.

3.12.3.1 Mar 23 1968/Data Sheet.

March 23, 1968

No tape or plotter record

	Flight Path			
	Planned		Actual	
	N	E	N	E
Home	818.5	561.3		
HST-VOR	809.5	551.6	810.5	552.3 Update
Met 1	819.0	530.0	820.3	529.1
	817.0	526.0		
	819.0	534.0		
	819.5	534.0		
	817.5	526.0		
	818.5	526.0		
	820.0	534.0		
Met 1	819.0	530.0	821.0	528.5 (Updated to 820.3, 529.1)
HST-VOR	809.5	551.6	811.0	551.8
Home	818.5	561.3	820.5	560.2
Wind Readings				
330 deg at 10 knots				
320 deg at 20				
330 deg at 18				
300 deg at 15				
330 deg at 15				

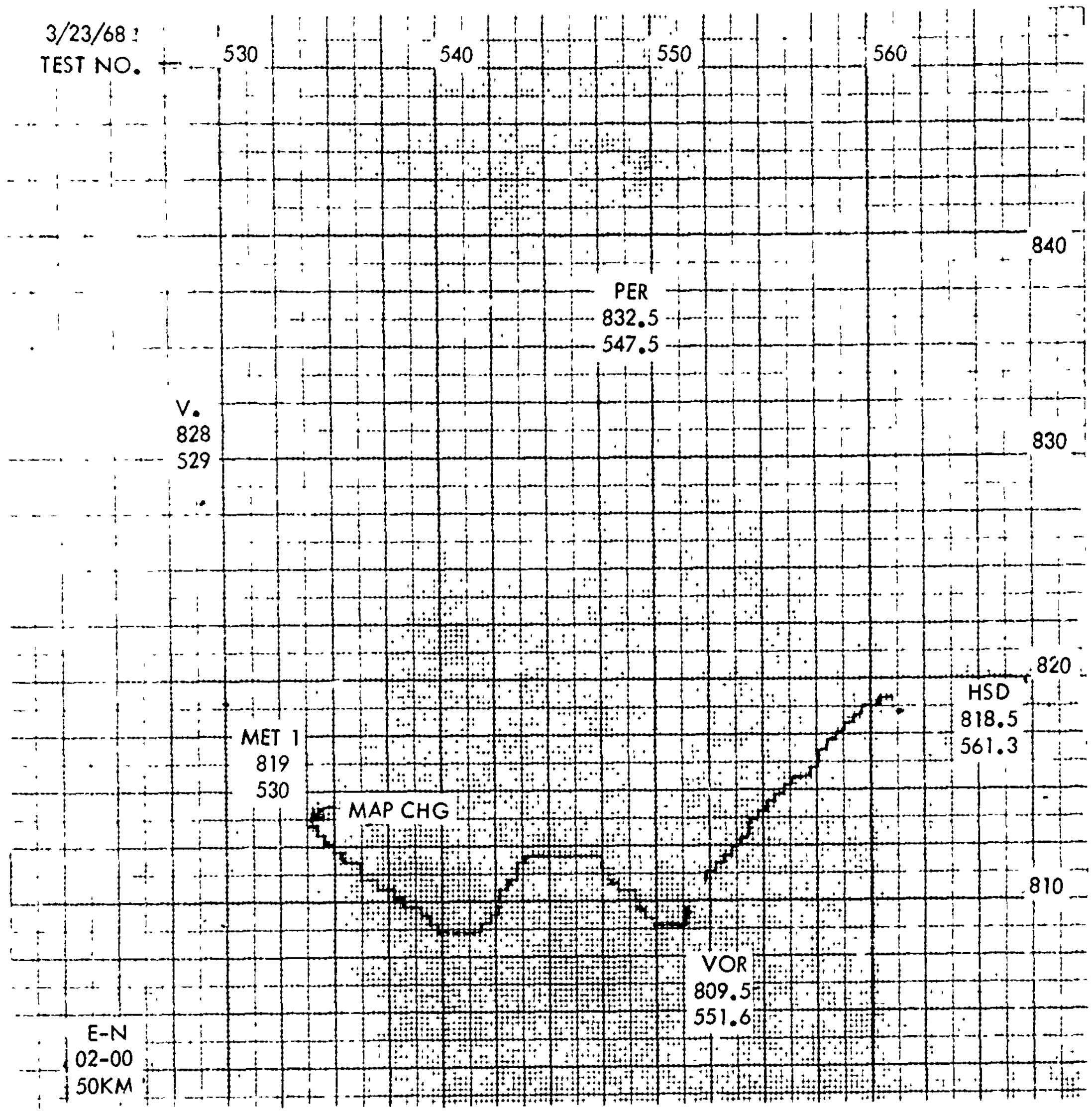


Figure 3-90. Test 530 UH1-D (89).

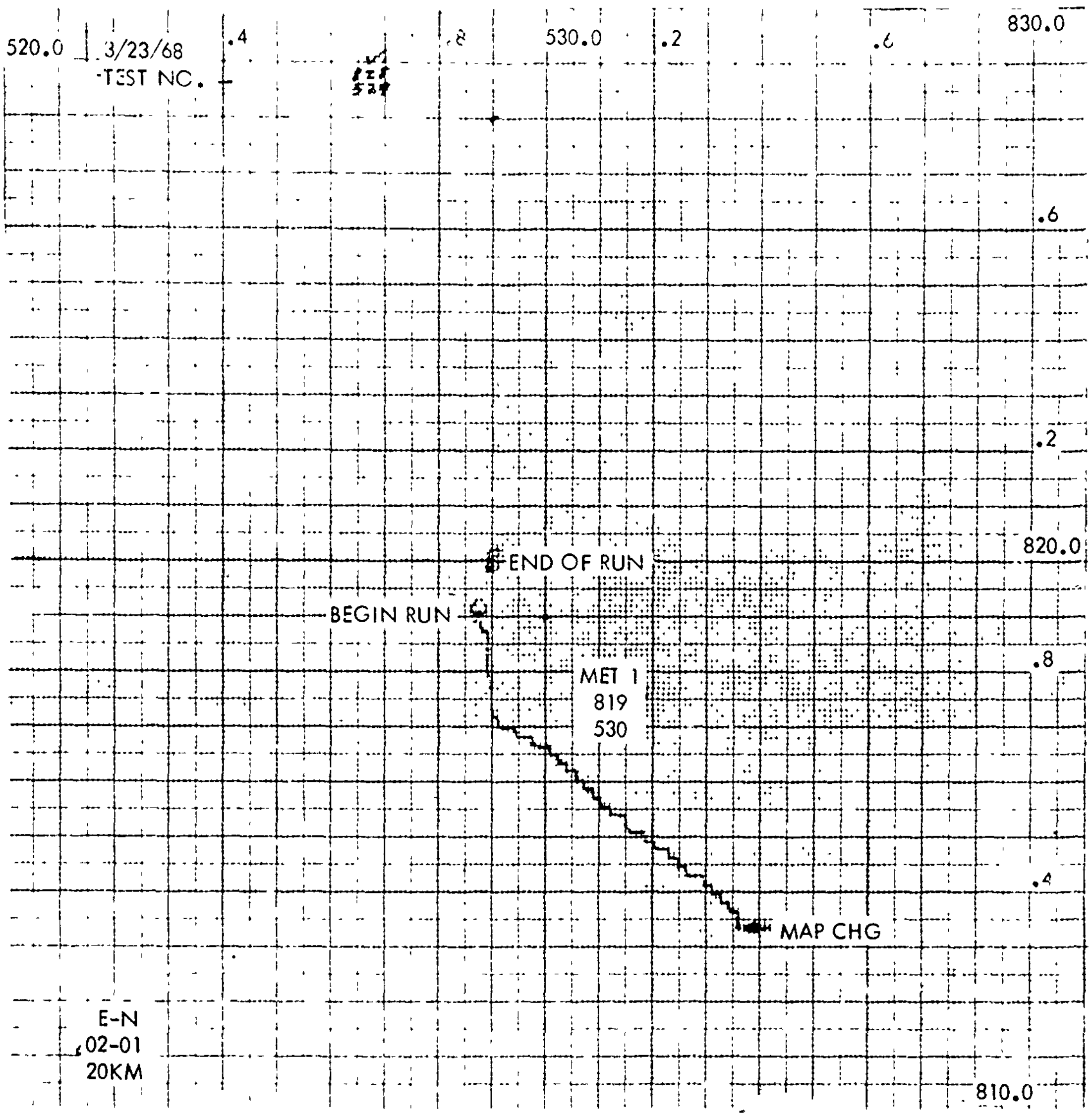


Figure 3-91. Test 529 UH1-D (89).

3.12.4 Aberdeen Flight

On 17 May 68 System 2, mounted on the UH 1D, was flown in the Aberdeen area. The object of the flight was to demonstrate that the system could be successfully operated on a helicopter, the primary criterion being a tape recording of the flight from which a meaningful printout could be obtained. The tape recorder had consistently failed on previous test flights. The flight was to be made against CN sources of convenience in the Aberdeen area.

3.12 4.1 Flight Data. The following data was taken during the flight·

8.4 deg West variation
38 deg Latitude
Winds reported at 6 knots 320 deg steady

Planned Flight	Checkpoints East	Checkpoints North	Actual East	Actual North	Comments
Phillips	95.0	93.5			
WASA Tower	86.8	98.2	101.1	103.4	Update
Quarry	95.5	120.0	96.4	115.4	Update
Holtwood Power	88.2	113.2	94.1	109.1	Update
WASA Tower	96.8	98.2	93.1	103.3	—
Phillips	95.0	93.5	88.7	92.9	—

Time

14:19 Takeoff CN background >50K on CH 2 and 3, CH 1 2.5K

14:25 WASA Tower CH 1—15K, CH 2—40K, CH 3—>50K
Flew upwind of quarry then circled it. No detections were noticed.
CH 1—10K, CH 2—50K, CH 3—>50K

14:41 Holtwood Dam—over water
CH 1—7.5K, CH 2—50K, CH 3—>50K

14:46 WASA Tower Plotter was not synced to Navigator at this point.
CH 1—7.5K, CH 2—40K, CH 3—>750K

14:48 Dump—Flew through smoke and had a detection on CH 1

14:51 Phillips

On landing it was noticed that the wrong dam was used to update the navigator on way back.

121715 set on thumbwheel switches.

Inhibit ON until computer disables were turned on for CH 2 and CH 3.

On two occasions, several digital lights came on (Prog, Range, Sync). They went off within one second.

Thirty-three minutes of tape were used (RTM reading).

3.12.4.2 Flight Results (Figures 3-92 through 3-94).

1. Navigator accuracy upon return to the WASA Tower indicated error at the WASA tower of 0.6KM South and 0.2KM East, after compensating for the incorrect update. This indicates an error of ~ 3.2 percent. Note that the position of the quarry on the map section was accurately located and plotted, which demonstrates compass subsystem and plotter accuracy, as well as navigator accuracy.

2. A plot of the flight taken from tape recorded data verified the above errors and demonstrated recorder operation (figure 3-94).

3. Plotter operation is demonstrated by the map section plot (figure 3-92). Note the effect of the incorrect update of the navigator. Also note that the plotter marked an off-course target in the vicinity of the dump (when corrected for the incorrect navigator update).

4. Chemical subsystem operation was demonstrated by plotting (figure 3-93 from the tape recording print-out) the detection of the smoke plume from the dump. The plot also indicates the alarm received from the analyzer as well as the background level and calculated alarm levels.

5. Operation of the data handling system was demonstrated by the data obtained from the tape recording; also by the offset and marked symbol made by the plotter when the smoke plume was detected.

3.12.4.3 Conclusions. The operation of the AMPD-224 system on a UH-1D helicopter without a failure of any part of the system demonstrates that a helicopter installation is feasible.

3.12.5 Installation on J0V-1B Mohawk

The second system was then installed on the second J0V-1B (592633) and several test flights made. Prior to formal flight testing, a complete checkout was performed (2 Oct 68—5 Oct 68).

Prior to starting system checkout, the following system changes were made.

1. A/D converter SN 1760 was replaced with A/D converter SN 1759, to ensure that the A/D converter was not the cause of random bits appearing on the A/D lines.

2. The analyzer SN 1 was removed from the system, and the CH 1 range switch was reset manually to 50K. The switch had been stuck between ranges 50K and 20K.

The J0V1-B-33 AMPD system was checked according to system test specifications which were developed during initial laboratory testing of the J0V1B Mohawk AMPD systems. The summarized results of the checkout follow.

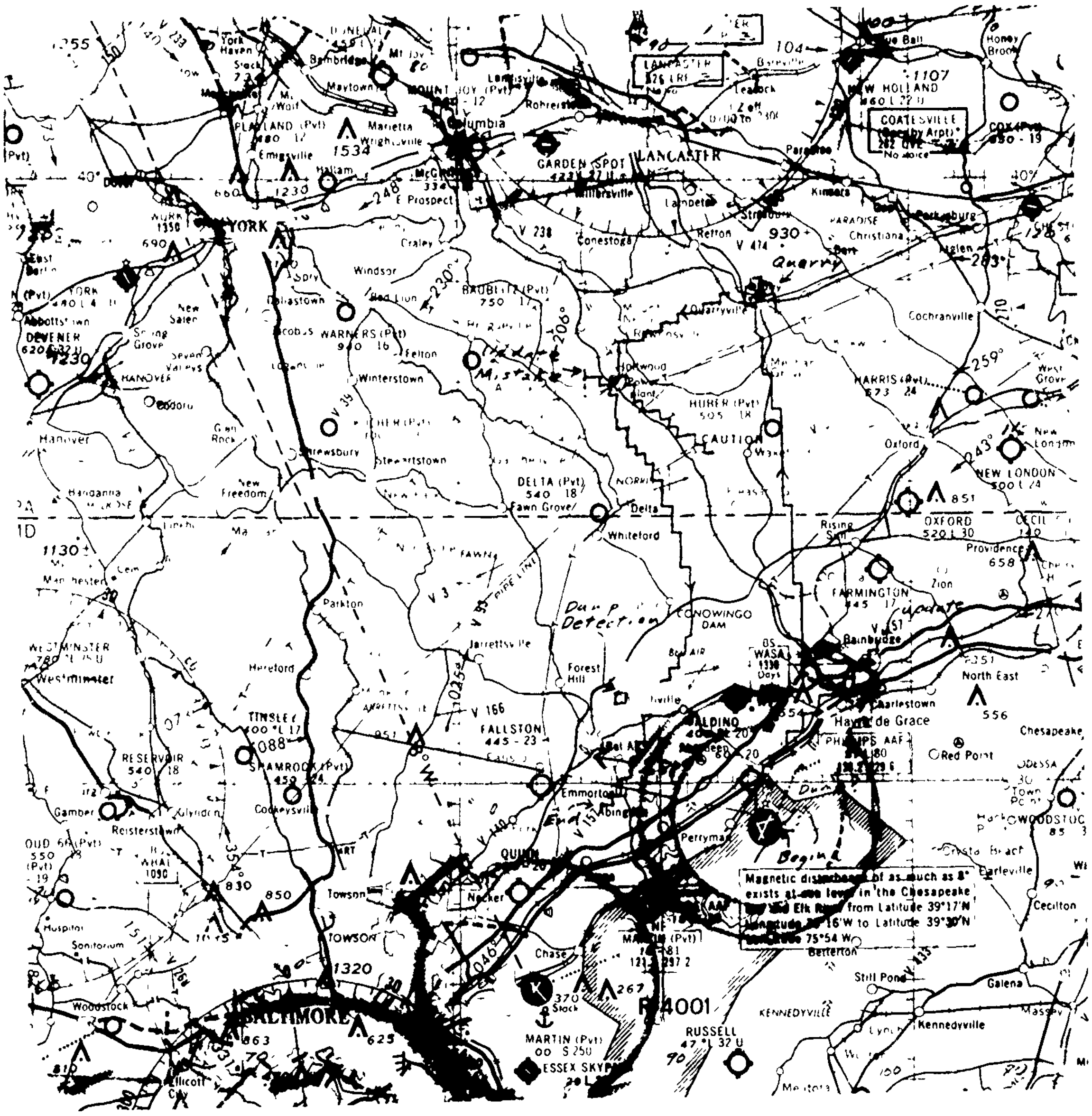


Figure 3-92. Navigation Flight—UH1-D (89).

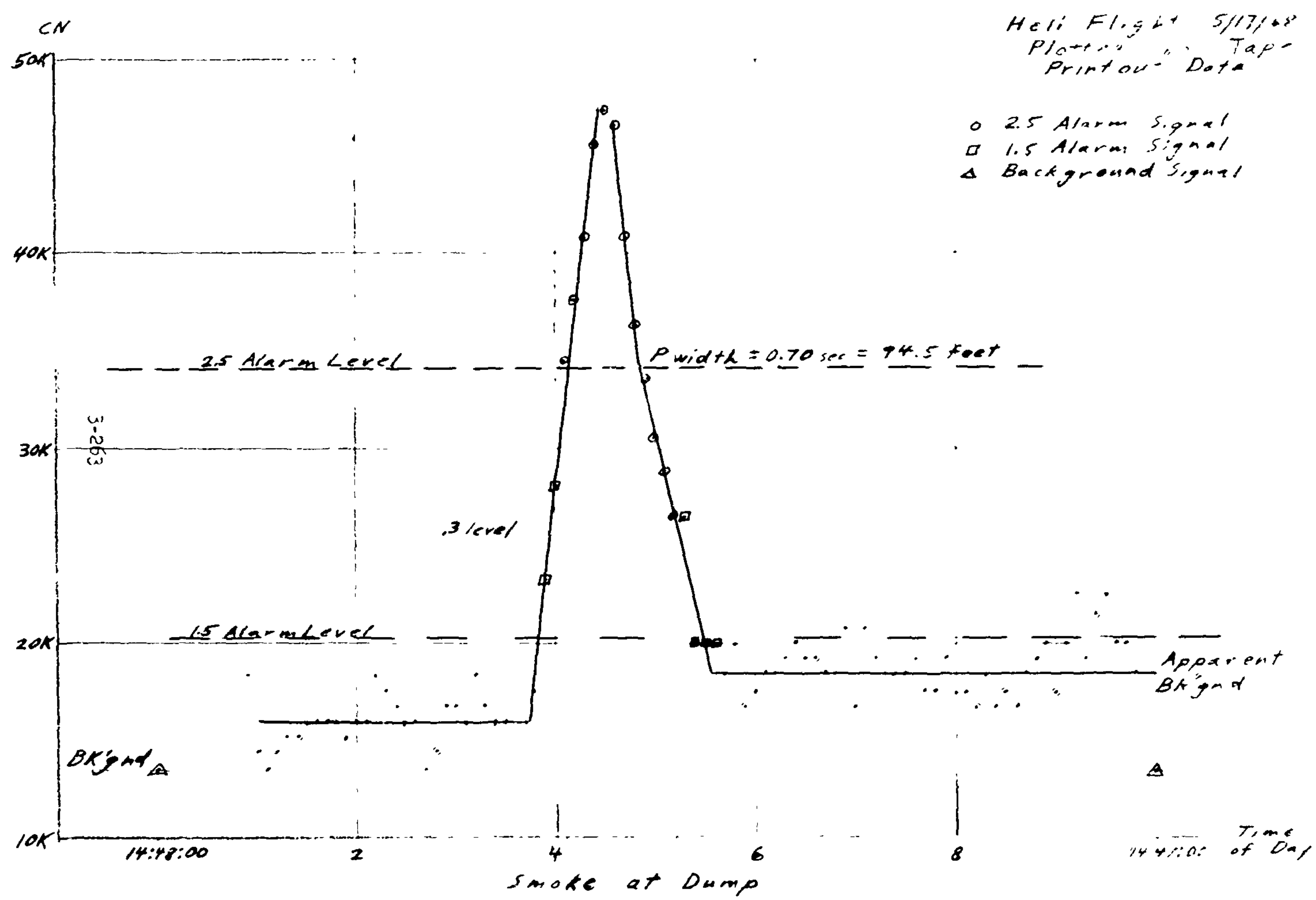


Figure 3-93. Plotted Alarm Signals--UH1-D (89).

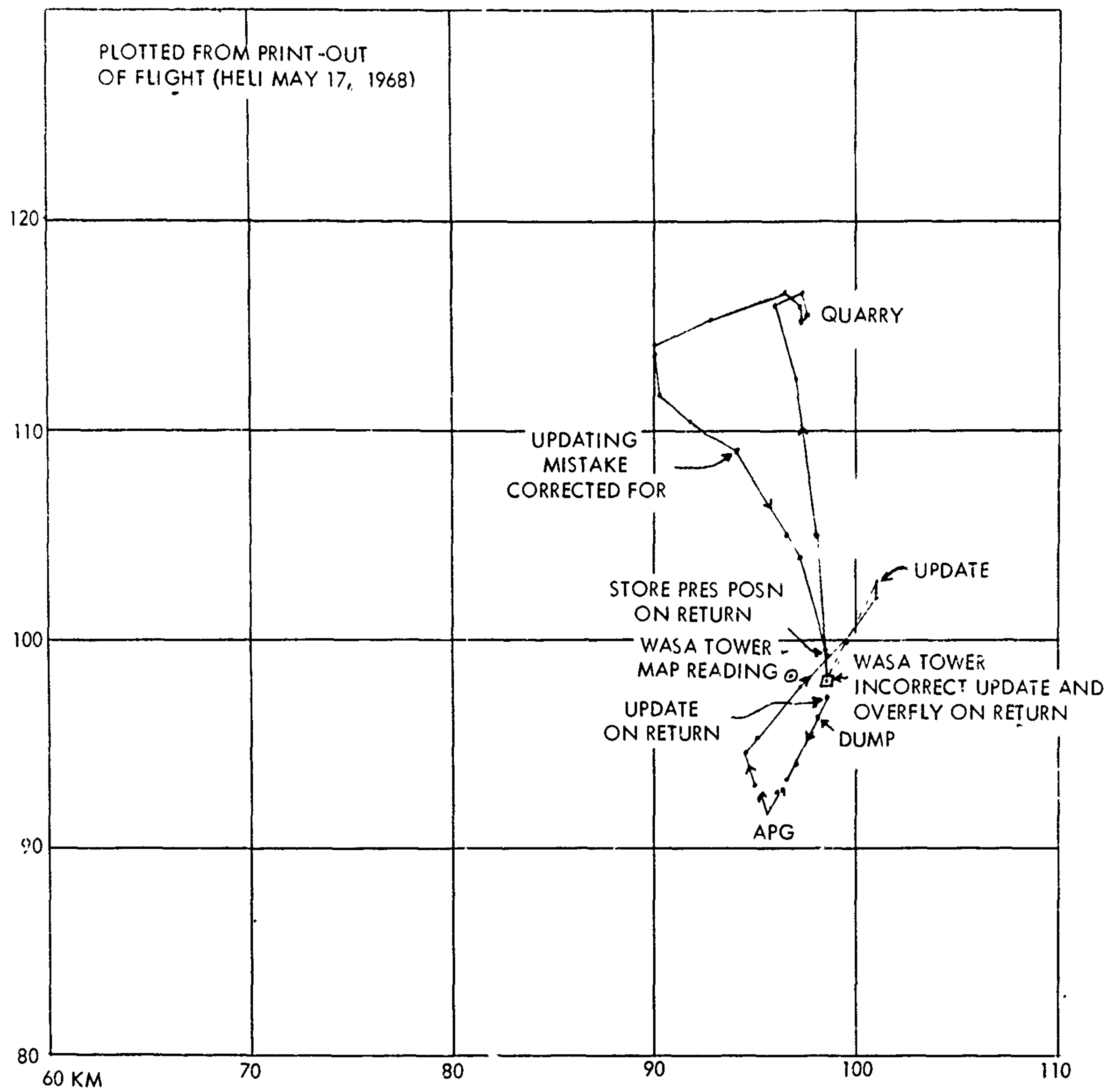


Figure 3-94. Flight—Plotted from Printout UH1-D (89).

3.12.6 Second System Checkout on Mohawk (592633)

3.12.6.1 Chemical Subsystem.

1. Corona converters were unavailable for checkout.

2. The converter heater modification was not checked (this checkout was performed by Field Service when the modification was performed).

3. The detectors were found to track within approximately 5 percent. The calibration was not checked with a Gardner counter.

4. The analyzer/detector signal interfsce was found to function normally in all respects.

5. The analyzer CH 1 range switch was found to hang-up when going from 50K to 20K in manual mode. The range switch contacts were cleaned with contact cleaner, and set at the 50K range.

   This problem has been a reoccuring one, and is due to failure of the mechanical reset in the switch. The log-AMP detector change will require that the range change function be eliminated, so this presents no problem for future system operation.

6. The detector simulation switches on the system test panel cannot be used together without loading down the ±15 vdc power supply in the analyzer. In the future, these test signals should be utilized one at a time.

3.12.6.2 Plotter Subsystem. The plotter in the system at the beginning of checkout caused the plotter circuit breaker to trip. This was due to a set of relay contacts being welded together, shorting 28 vdc to ground. The relay was repaired and the proper relay diode was installed by Field Service.

Before the plotter failed, the cover hinge was found to interfere with the pen carriage movement along the rails. The pen was also found to oscillate near map edges. The backup plotter subsystem was installed in the aircraft, and it functioned normally in all respects.

3.12.6.3 Meteorological Subsystem. The MRI unit was not in calibration, due to the lack of a 4.5-Hz signal source. The MRI unit was checked out in the system in this uncalibrated condition.

1. Temperature was found to be accurate to within 5 percent.

2. The 10 range CAL mode output was found to be in error by +1 bit.

3. MRI/System interface was normal.

3.12.6.4 Data Handling Subsystem.

1. Computer memory was lost when the navigator was switched from STBY to LAND mode. At the conclusion of the system checkout, the system was turned completely on. The power circuit breakers and navigator mode switch were turned OFF/ON, and the computer memory could not be lost. No explanation for the memory loss was found.

2. All multiplexing of the discretes function without fault.

3. A recorder tape was made while vibrating the multiplexer, and it indicated that the analog signals were still jumping.

   After this tape was made, the 5v wind potentiometer voltage was measured at Pod 2. This voltage was approximately 5. 5 vdc. At the same time, the +15-vdc output of the Pod 1 ±15-vdc power supply was found to have one volt P to P of noise.

   The problem unexplainedly disappeared, and the wind potentiometer voltage dropped to 5. 009 (fluke differential voltmeter). The noise on the +15v line also disappeared. The problem appears to be related to the noise on the +15v line.

   Some ground pins in the multiplexer were found to be as high as 1 ohm above ground. The grounds on all multiplexer blocks were tied together and a new recorder tape was made. During the running of the tape, multiplexer and the +15v supply in Pod 1 were vibrated, and the 5v wind potentiometer excitation was monitored with a fluke differential voltmeter.

   The 5v wind potentiometer excitation did not vary, and the recorder tape indicated no analog signal jumping. The ground problem in the multiplexer may have caused the analog signal jumping. This should be substantiated with a test flight.

4. The A/D converter converted all analog signals to within specified signal plus conversion accuracy.

5. The S/D converter converted all synchro signals to within specified signal plus conversion accuracy.

6. The recorder functioned normally and three test tapes were run.

7. The TOD clock functioned normally.

8. The source position display is not connected to lamp test. The wires are dead-ended in the tactical display panel.

3. 12. 6. 5 Navigator Computer Subsystem.

1. Wind calculation functioned correctly.

2. The TAS transmitter/navigator interface appears to have a 10-kt error. With the pitot tube tester set to 180 Kts, the G/S indicated on the VSI with zero wind is 170 Kts.

3. The present position digital readout on the control indicator has approximately 78 meters average error in both N/S and E/W displays. This error does not require any gear train adjustment (figures 3-95 and 3-96).

3. 12. 6. 6 Navigator Doppler Subsystem.

1. The wind direction control on the control indicator still controls the VSI directional pointer in wind-set or wind-read modes. This should be modified so that the VSI directional pointer displays true track regardless of the setting of the wind/read/set switch on the VSI.

2. The doppler subsystem functioned normally.

3.12.6.7 Compass Subsystem.

1. The compass subsystem functioned normally in all respects.

3.12.6.8 Test Problems. Four test problems were run (figures 3-97 through 3-100). The test problems define an area in which the offset plots should have occured. In all cases, the plots occured within the specified area.

After the completion of each sample problem, the exact data used by the Mk 12 computer is read out and recorded. This data is used to establish corrected values of track, wind and source location. The corrected source location is indicated by · and corrected track and wind is indicated by _____ __ _____ _. Assuming no inaccuracy in plotting the corrected source location, the error between the plotter mark and the corrected source is system error incurred after source calculation in the Mk 12 computer.

The source location digital readout indicated the following for each problem.

Problem 1	106E	105N
Problem 2	110E	113N
Problem 3	090E	080N
Problem 4	082E	090N

The source location was within the desired accuracy on all but the East coordinates of problems 3 and 4. These readouts have errors of 10 percent and 30 percent respectively.

Test maps Nos. 3 (figure 3-101) and 4 (figure 3-102) were rerun to check for an indicated error in the source location for them. The following was recorded:

Test Map	Source Location	Map Location
3	100 East 75 North	10.0 East 7.5 North
4	106 East 93 North	10.6 East 9.1 North

(See figures 3-101 and 3-102.)

The indicated error is within the specified limits.

3.12.6.9 Test Flight. A test flight was made 9 Oct 68 to verify the accuracy of the airspeed and side-slip adjustments and check total system operation. Printout of the flight indicated the following:

A. Side-Slip error = 0.35 deg ccw
B. Airspeed error = 1.7 knots low
C. Turbulence = 0.16 to 0.32 (Phase 2 flights average > 1.0)
D. No analog noise was apparent

Side-slip and airspeed are within the specified limits of ±0.5 degree side-slip and ±2.0 knots airspeed. All components of the system operated properly.

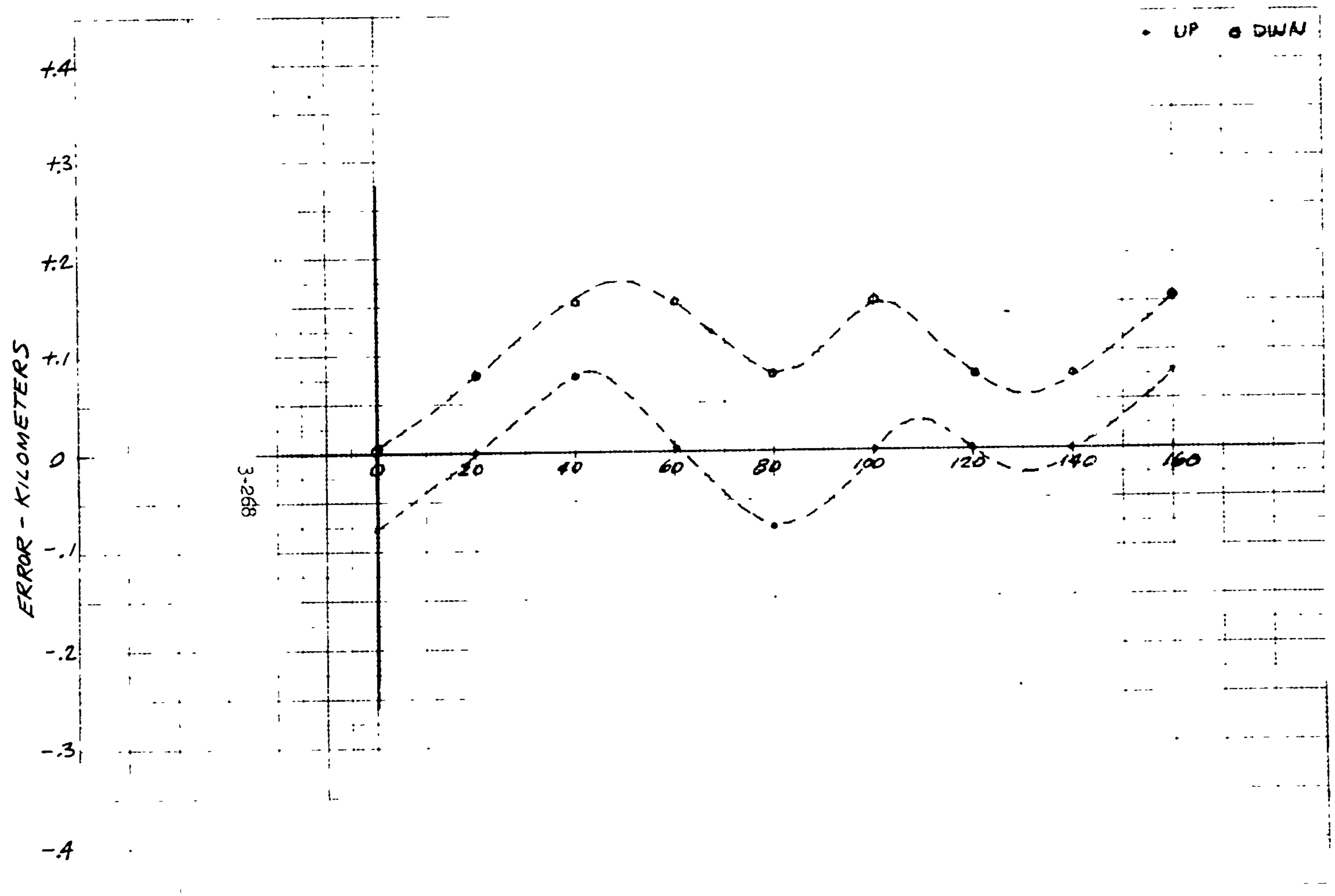


Figure 3-95. E/W Control Indicator (Navigator) PP Calibration.

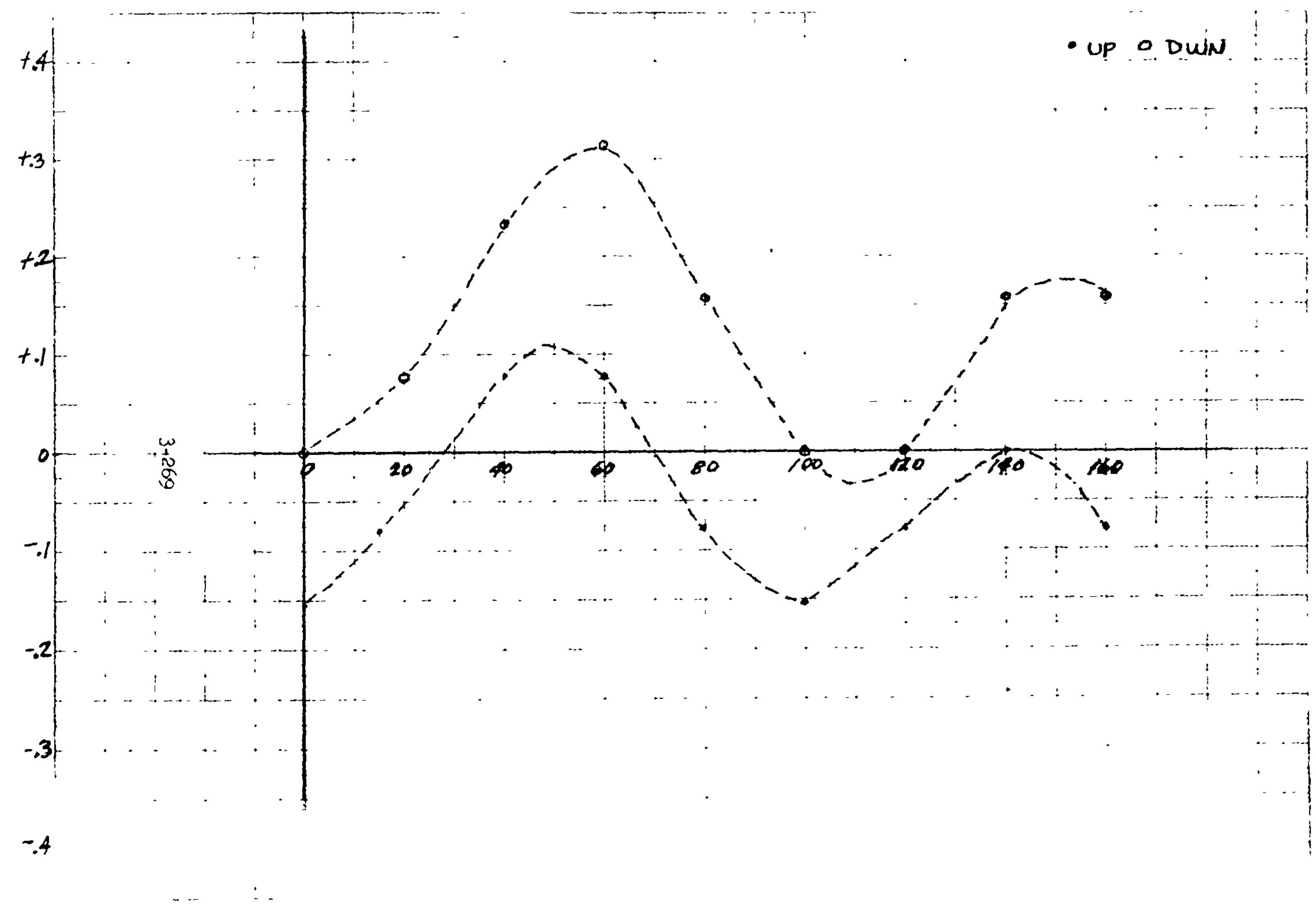


Figure 3-96. N/S Control Indicator (Navigator) PP Calibration Check J0V1-B (33).

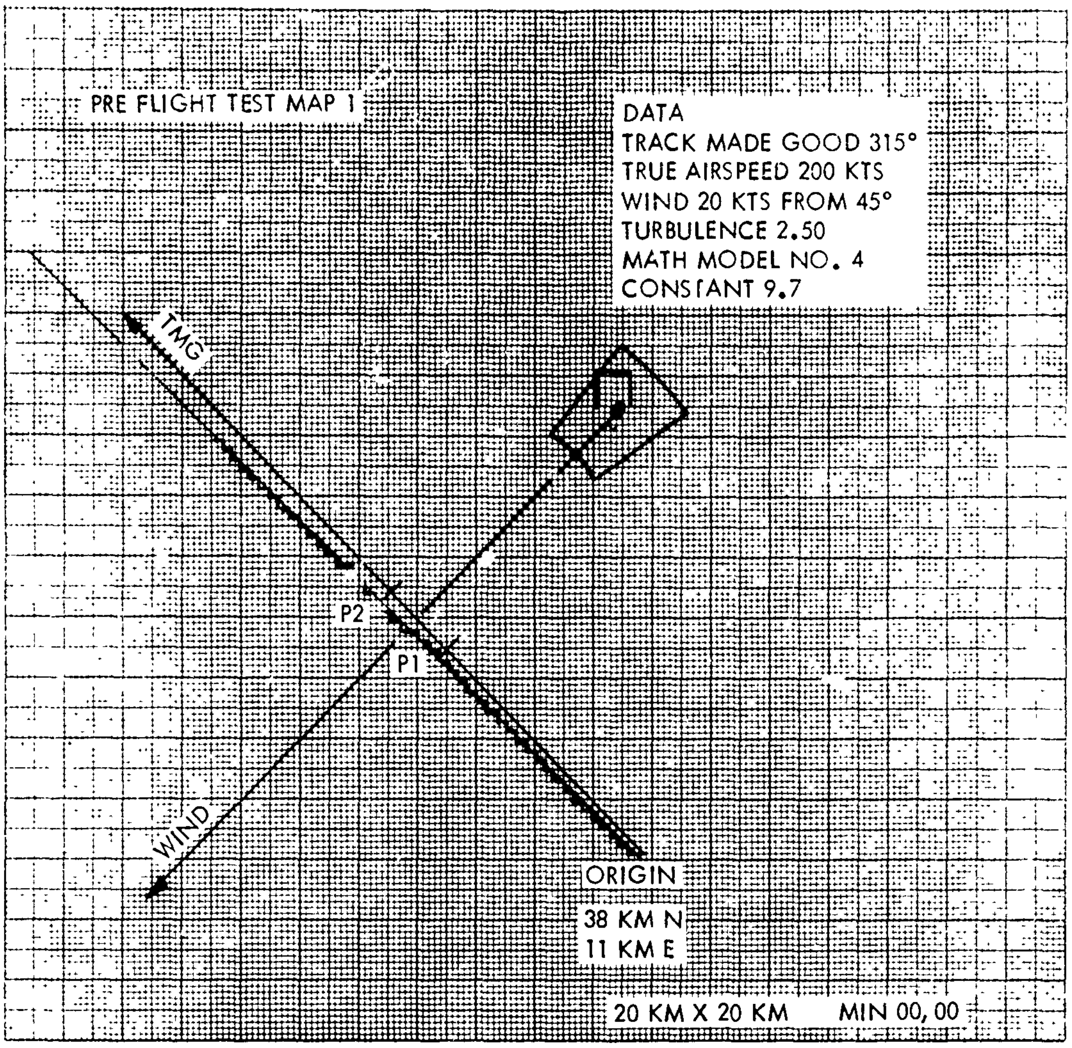


Figure 3-97. Preflight Test Map 1—J0V1-B (33).

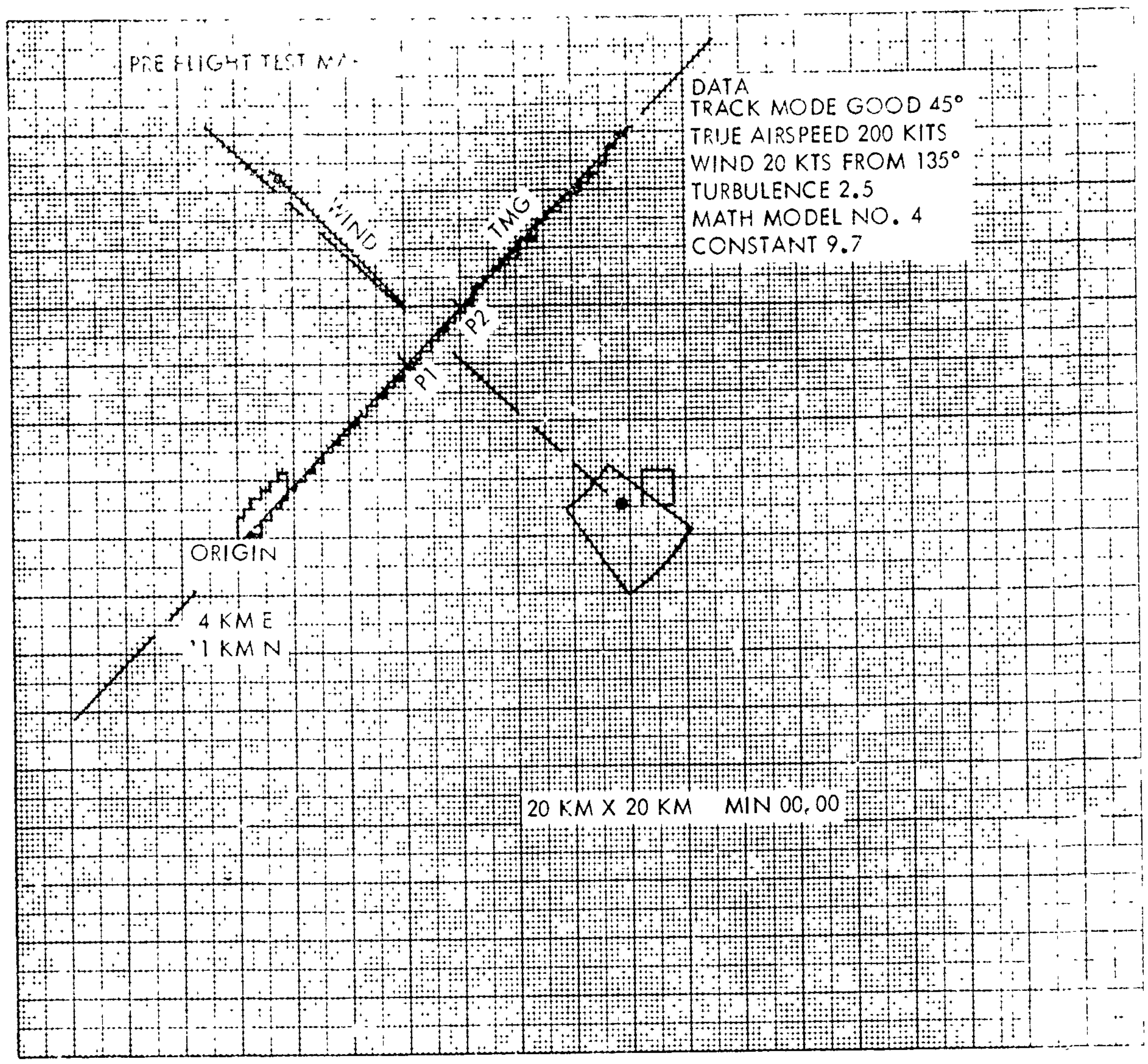


Figure 3-98. Preflight Test Map 2—J0V1-B (33).

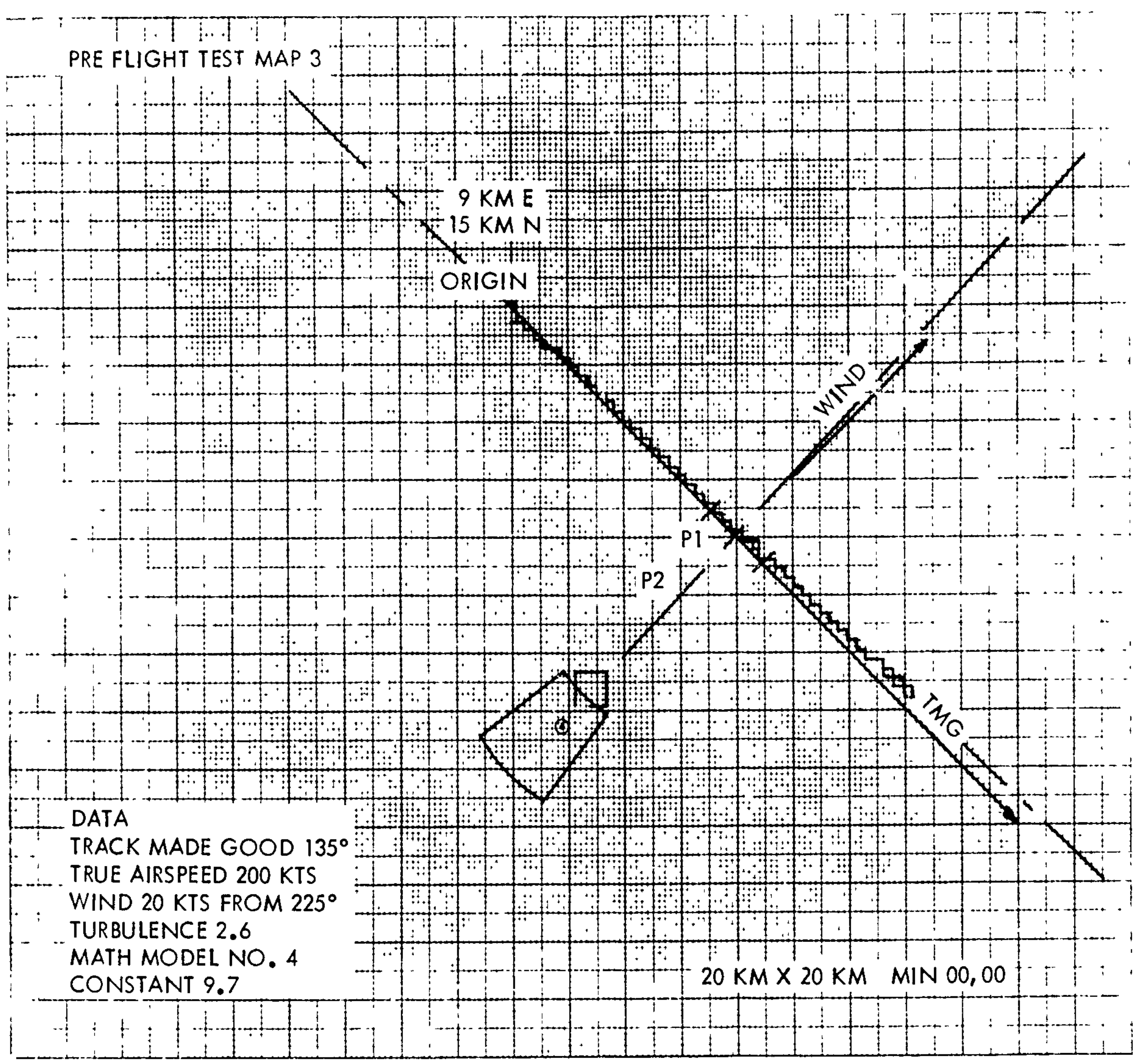


Figure 3-99. Preflight Test Map 3—J0V1-B (33).

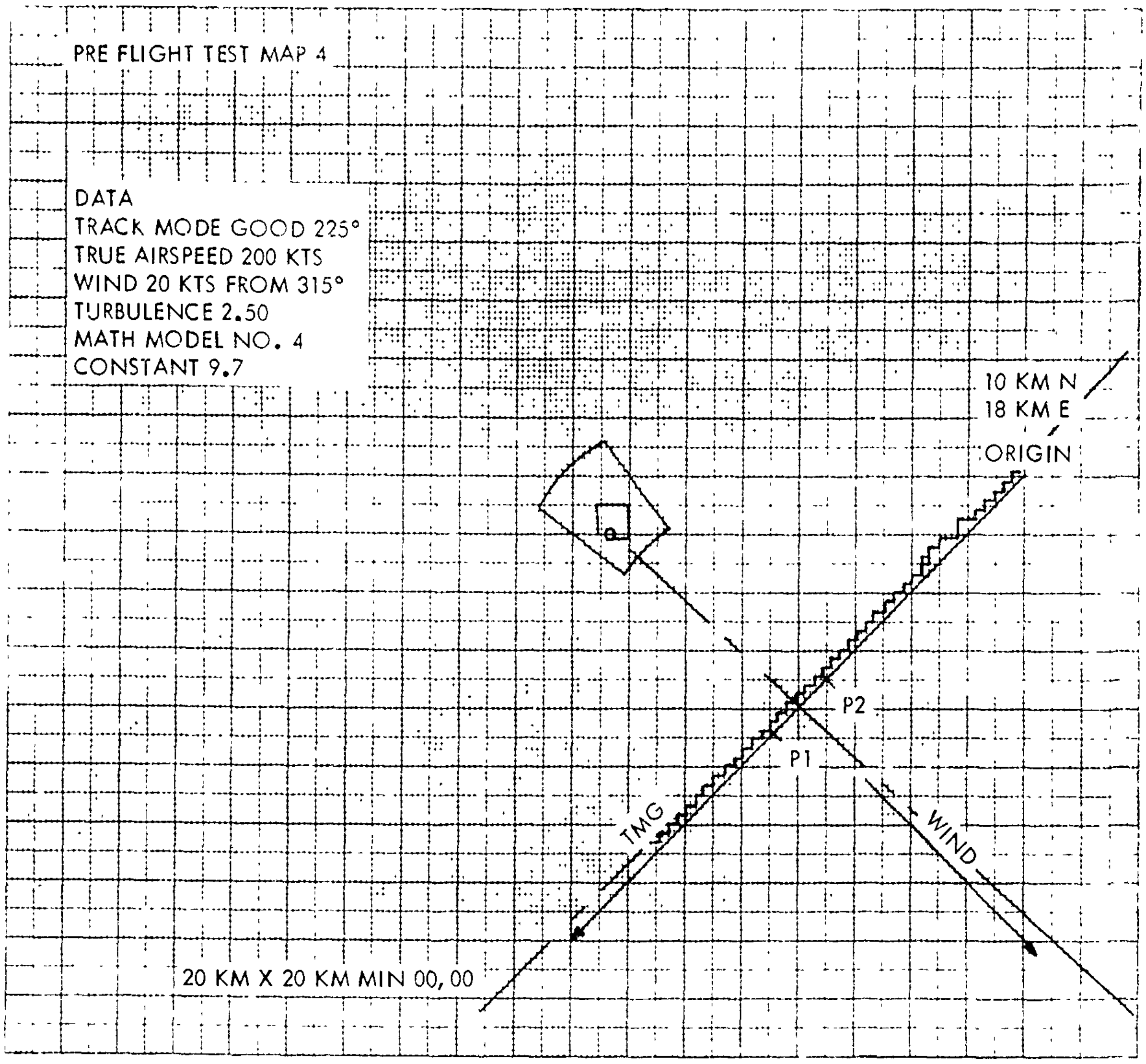


Figure 3-100. Preflight Test Map 4—J0V1-B (33).

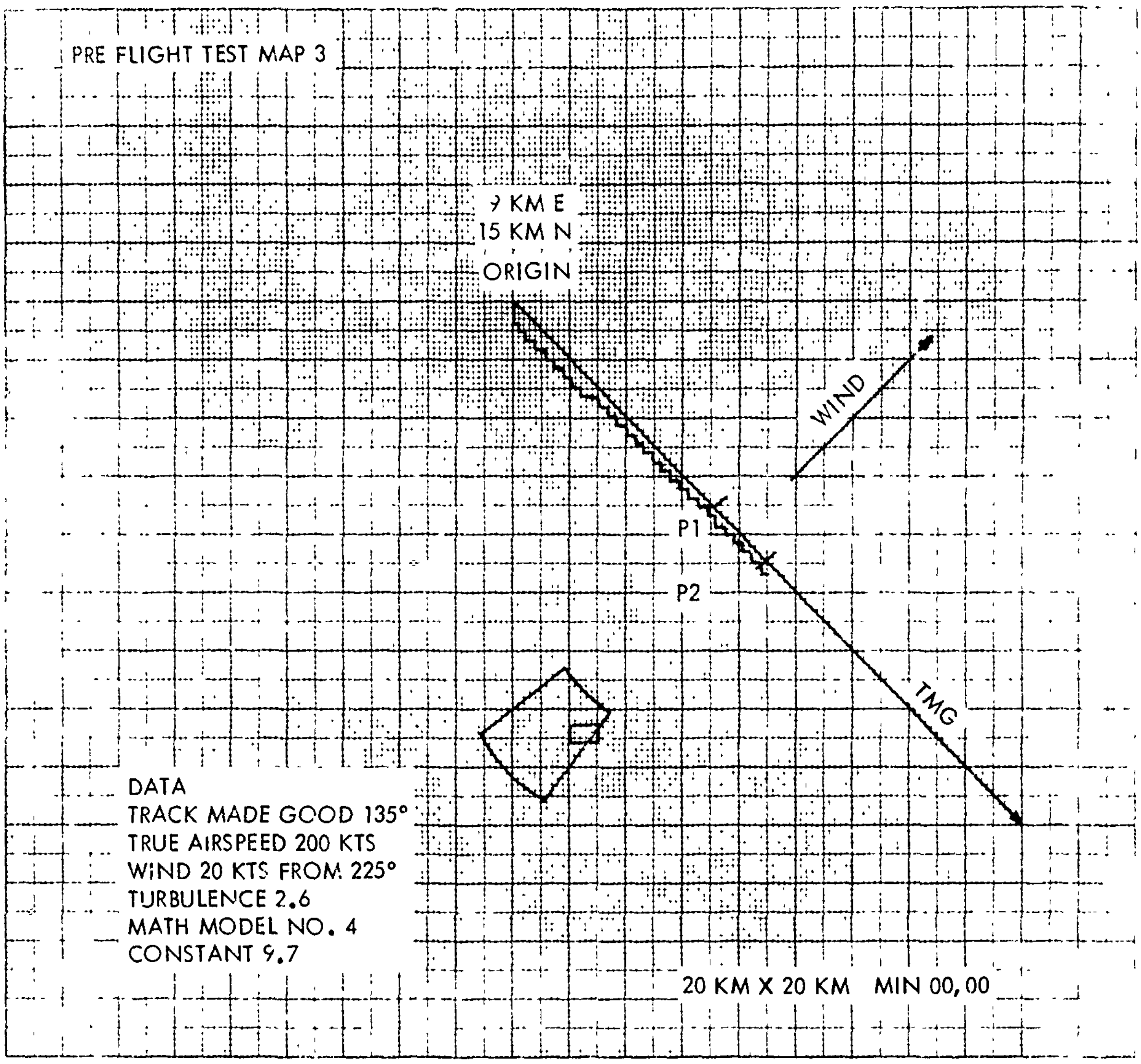


Figure 3-101. Preflight Test Map 3--J0V1-B (33).

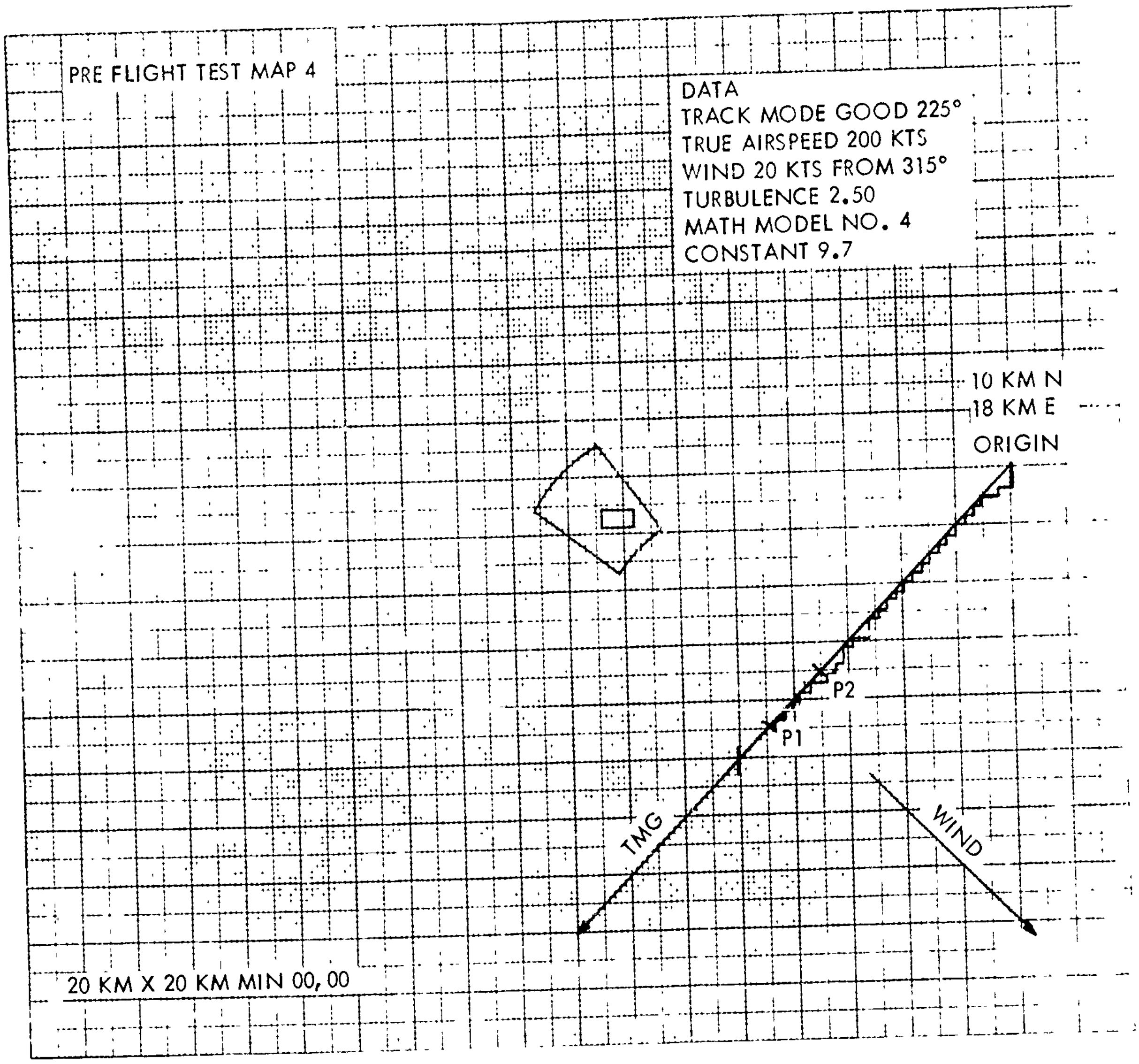


Figure 3-102. Preflight Test Map 4—J0V1-B (33).

3.12.6.10 Test Flight/Operability. A flight of record was made on 22 Oct 68 on the JOV1-B (92633). The object of flight test No. 506 was to demonstrate system operability. The criteria of operability being the following (per R. F. Power's memorandum of 19 Sept 68).

1. Plot aircraft position

2. Provide good VSI data

3. Detect large CN sources (for example, ferry boat) at 0-500 meters

4. Plot (with gross accuracy) large CN sources of opportunity

5. Record meteorological, aircraft, and detector data and make a successful printout

The flight data is as follows:

Variation 9 deg W
Latitude 39 degrees
Wind (reported) 170 degrees 10 knots

Check Point	Planned N	Planned E	Actual N N	Actual N E	Time	Comments
APG	90.0	74.5	90.0	74.5	13:16	BCD = 001041 CI*
DOV	48.6	128.8	51.7	133.6	13:23	
ATR	13.3	155.0	18.6	154.7	13:34	
ATR	13.3	155.0	15.8	155.3	14:05	
APG	90.0	74.5	92.8	64.4	14:27	

Test	Wind Dig	Wind Knots	G/S	A/S	Time	Detectors Bk'grnd	Detectors Rng	Th	Turb	SS	Temp
115°	190°	20	195	197	13:22	30	20K	1.5	.2v	2.2v	2.6v
150°	-	-	187	196	13:31	45-50	20K	1.5	.3	2.1	2.6
320°	140°	40	235	195	14:09				.1	2.2	2.8

NOTES:
a. Altitude--Memory and OFF indication at 14:09
b. Altitude indication was 1200 ft (aircraft at 2500 ft)
c. Navigator--Memory at 14:13 for just a few seconds
d. 71 minutes of tape used
e. Ferry was just leaving canal just north of Cape May Point upon arrival
f. Objects on ground and buoy were used as track markers during runs

3.12.6.11 Test Flight Results.

1. The present position was stored when a detection was noticed which appeared to correspond to the ferry's plume. The proximity of a small village and factory may have caused some of the detections especially during the first couple of runs.

2. Printout of the first run doesn't identify the ferry boat. Other runs seem to have good definition of the ferry's plume.

3. The map section made of the cape area didn't have the proper scale code (20KM instead of 50KM) as verified by the printout.

4. The present position was mistakenly slewed between the 3rd and 4th runs. The resultant error was ~0.5N 1.0E (from printout).

5. Navigator error--APG to ATR -4.3N -0.3E ~5.6%N 0.4%E
   ATR to APG +0.3N +10.4E ~0.4%N 12.9%E

   (This error is excessive. The printout indicates that it is related to a high G/S during the return leg. The loss of altitude information may be related to this error also.)

6. Wind Calibration--Side-Slip error = 0.158 deg CCW
   Airspeed error = 4.60 knots low

   This information may not be as good as desired because the runs were made across wind instead of with it. Also, the headings weren't closely controlled.

7. Plotter—Most of the detections were obscured by the legs of the runs. The only detection plots which show clearly are 8E and 9W. The indicated offsets are 4KM for both plots. The source location indicated 2.1KM for 8E and 4.0KM for 9W. This indicates a plotting error of 0.4 cm. The normal plotter quantizing would account for the error.

8. The aeronautical chart isn't accurate enough to give an accurate outline of the test area. The error is 3.5KM-N, 1.5 KM-E at ATR, and indeterminant for the test area.

3.12.6.12 <u>Conclusions:</u>

1. The primary objective of the flight was accomplished for the following reasons:

   a. The source of CN was detected.

   b. Offsets were marked on a map section in the area of the source.

   c. Corresponding source locations were received.

   d. The plotter followed properly from one map section to another.

   e. A tape recording was made and properly printed-out.

   f. There were no system failures prior to or during the detection runs.

2. The navigator developed error in present position, and altitude information was lost during the last leg of the flight (ATR to APG).

3. System operability has been demonstrated in that the system performs all of its expected operations with reasonable accuracy—except that the navigator did have excessive error in present position at the end of the flight and the altimeter failed during the last leg.

GENERAL ELECTRIC

REV NO 10/22/68

South Wind

CONT ON SHEET SH NO

TITLE **SAMPLE FLIGHT PLAN**

CONT ON SHEET SH NO

FIRST MADE FOR

REVISIONS

BASE COORDINATES N 900 E 745

Pres. Posn. (at point of Section)

DEST.	FUNC.	NORTH	EAST	COURSE	VAR	BEACON	REMARKS
DEST. 1	SET					N 334	Bk'gnd = 30 on 20K Rng.
1W	READ	370	1794		9.0W	E 826	
DEST. 2	SET					N 351	
2E	READ	349	1728			E 754	
DEST. 1	SET					N 346	
'W	READ	350	1737			E 744	
DEST. 2	SET					N 341	
4E	READ	350	17-3			E 390	?
DEST. 1	SET					N 319	
5W	READ	341	1732			E 7-?	
DEST. 2	SET					N 319	
6E	READ	344	1734			E 752	
DEST. 1	SET					N 31-	
7W	READ	329	1697	?		E 729	
DEST. 2	SET					N 310	
8E	READ	332	1727			E 796	
DEST. 1	SET					N 275	
9W	READ	374	1722			E 726	14:01
DEST. 2	SET					N	
	READ					E	
DEST. 1	SET					N	
	READ					E	
DEST. 2	SET					N	
	READ					E	
DEST. 1	SET					N	
	READ					E	
DEST. 2	SET					N	
	READ					E	
DEST. 1	SET					N	
	READ					E	

PRINTS TO

MADE BY | APPROVALS | DIV OR DEPT

ISSUED | LOCATION | CONT ON SHEET | SH NO

PF-609-WA (9-66) PRINTED IN U.S.A. | CODE IDENT NO

Figure 3-103. Sample Flight Plan.

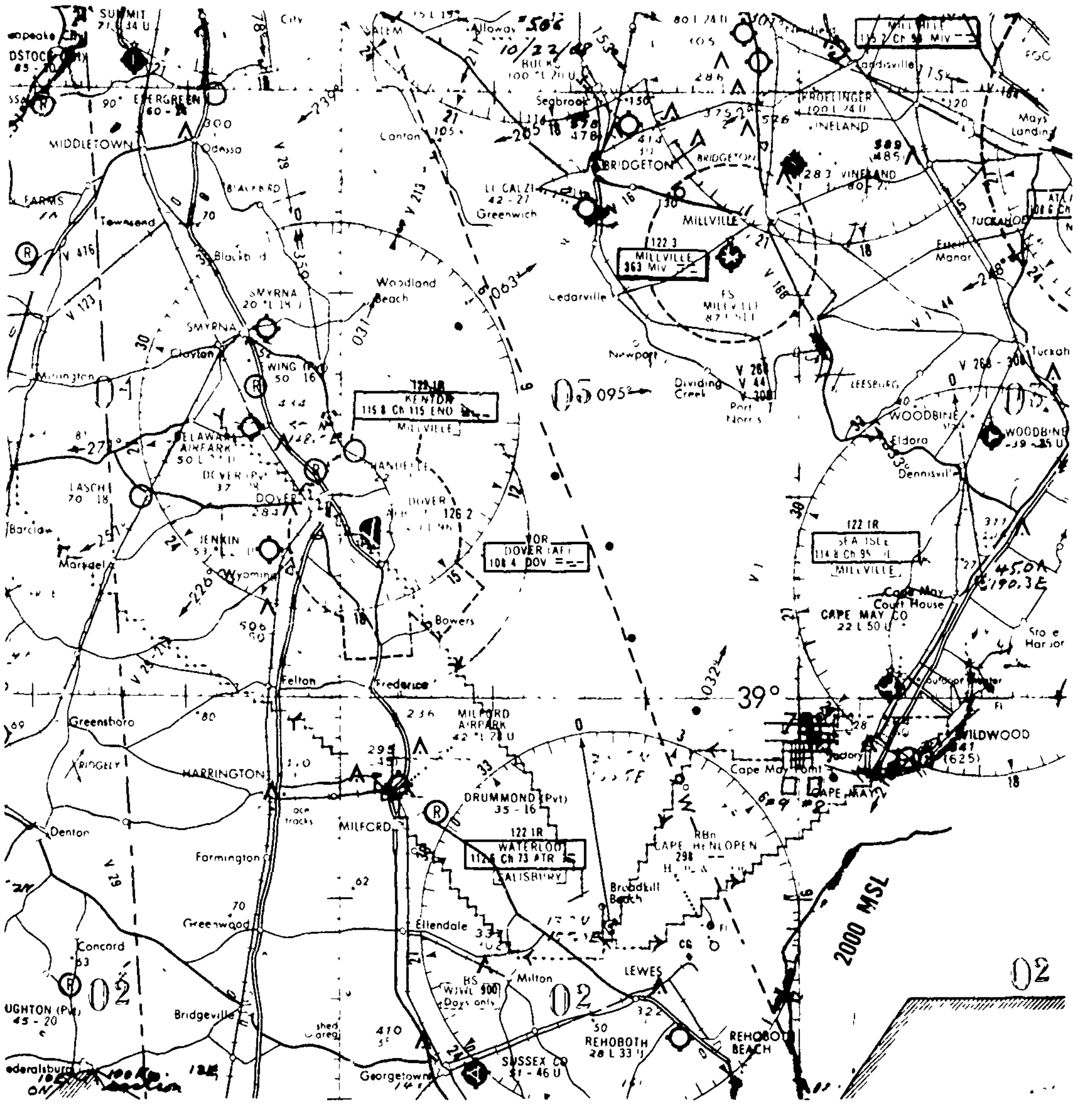


Figure 3-104. Test 506—J0V1-B (33) Map.

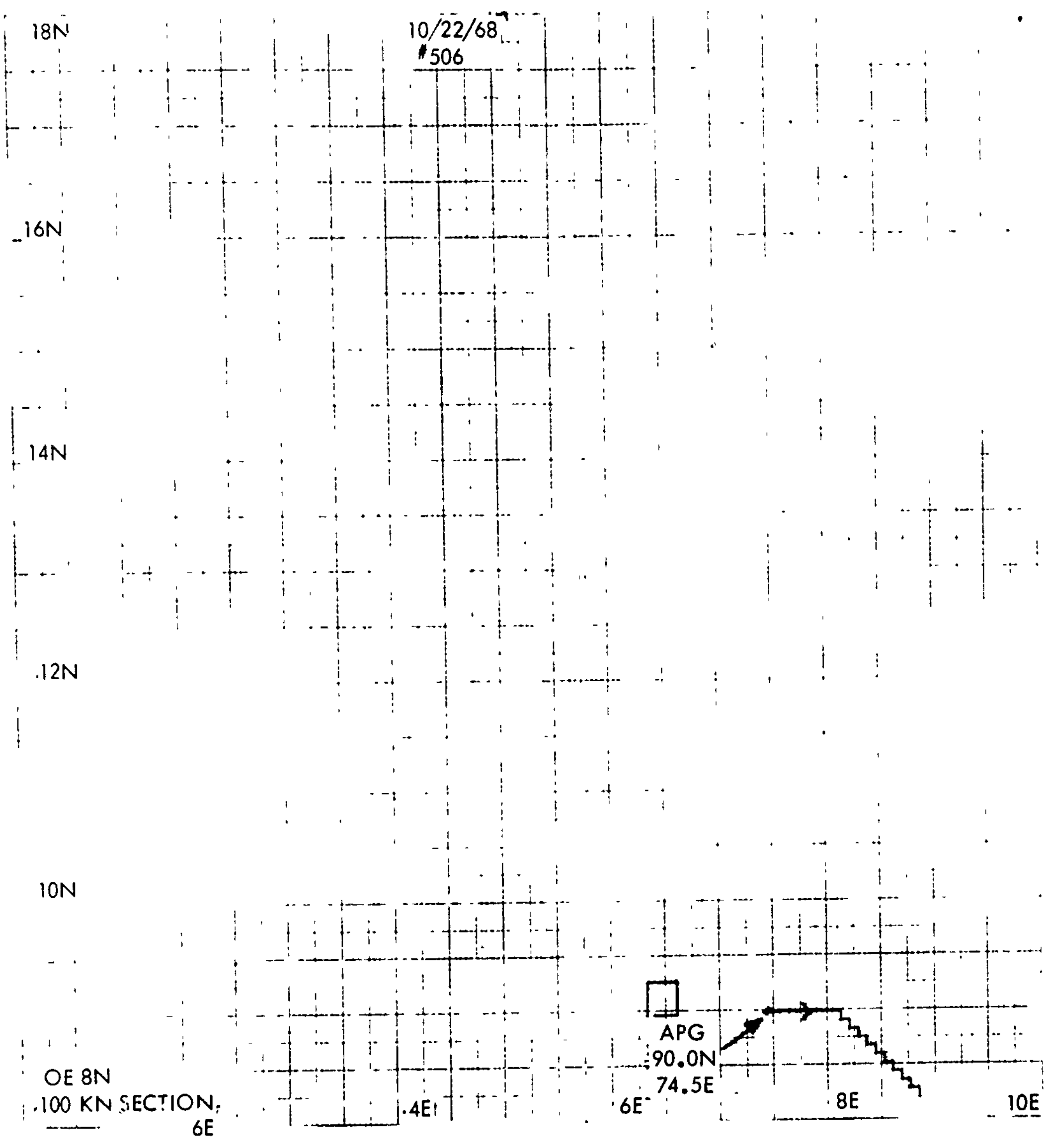


Figure 3-105. Test 506—J0V1-B (33).

3.13 DOCUMENTATION

The documentation developed throughout the duration of the contract for the design and manufacture of the AMPD-224 system is summarized in table following. The drawing quality is in general to good commercial practice. The listing is by unit name and system unit number. The group numbers refer to those in the documentation package supplied as a contract item. For a further breakdown of the drawings and specifications supplied, see the Documentation Index supplied with the documentation package.

The operational and maintenance manuals supplied as a part of the contract, cover the system, detectors, converters and multiplexer. Outside vendor manuals are also supplied. These items are discussed in paragraph 4.2.

TABLE 3-17. DOCUMENTATION LISTING

Item No.	Title	AMPD-2 Unit No.	Index Listing	Remarks
1.	Tactical Display Panel	1A1	Group 1	
2.	System List Panel	1A2	Group 2	
3.	Digital Control Panel	1A3	Group 8	
4.	Cockpit Junction Box	1A4	Group 7	
5.	Analyzer	3	Group 4	See also GEK 5022, Attachment 14 of AMPD system Manual GEK 5019
6.	Compass Subsystem			See vendor manual, attachment 5 of AMPD system manual GEK 5019
	a. Compass Controller	4	None	
	b. Compass Transmitter	208	None	
	c. Amplifier Electronic Control	206	None	Note: b only Vendor: Sparry Phoenix P.O. Box 2529 Phoenix, Arizona Part No. 620359
	d. Displacement Gyroscope	207	None	
7.	Navigation Set Subsystem			See also vendor manual, attachment 1 of AMPD system manual GEK 5019
	a. Control Indicator	6	None	
	b. Altitude Indicator	7	None	
	c. Velocity Steering Indicator	8	None	
	d. Navigation Computer Modified	201	Group 3	
	e. Computer Junction Box Modified	200	Group 3	
	f. Antenna	202	None	
	g. Doppler Junction Box Modified	203	Group 3	
	h. Receiver-Transmitter	204	None	
	i. Frequency Tracker	205	None	
	j. True Air Speed Transmitter	210	None	

Table 3-17. Documentation Listing (Continued)

Item No.	Title	AMPD-2 Unit No.	Index Listing	Remarks
8.	Power Panel	9	Group 5	
9.	Plotter Subsystem a. Plotter Display b. Plotter Memory Computer	 11 12	Group 20 Group 20	See also vendor manual, attachment 8 of AMPD system manual GEK 5019
10.	System Junction Box	13	Group 6	
11.	Self Destruct Panel	14	None	Note: The Pilots Destruct Panel is not included in the AMPD system; however, the wiring from the system junction box to pods has been installed.
12.	Display Power Supply	15	Group 1	
13.	Meteorological Subsystem a. Air Temperature Sensor b. Turbulence Sensor	100 114 116	Group 9 Group 9 Group 9	See also vendor manual, attachment 6 of AMPD system manual GEK 5019
14.	DRO Power Supply	102	Group 10	See also vendor manual, attachment of AMPD system manual GEK 5019
15.	Computer Program Unit	103	Group 10	Same as item 14
16.	Computer Memory Unit	104	Group 10	Same as item 14
17.	Kennedy Recorder	105	Group 11	See also vendor manual, attachment 2 of AMPD system manual GEK 5019
18.	Synchro-to-Digital Converter	106	Group 12	See also vendor manual, attachment 3 of AMPD system manual GEK 5019
19.	Multiplexer	107	Group 25	See also vendor manual, attachment 7 and GEK 5021, attachment 13 of AMPD system manual GEK 5019
20.	RC-95 Power Supply	108	Group 13	
21.	RC-95 D/A Converter (B) (A)	109 110	Group 13 Group 13	

Table 3-17. Documentation Listing (Continued)

Item No.	Title	AMPD-2 Unit No.	Index Listing	Remarks
22.	RC-95 A/D Converter	111	Group 14	
23.	Filter Box	117	Group 29	See FBD No. 6 of Group 27
24.	Power Supply ±15V	118	Group 15	
25.	Power Supply +15V	119	Group 16	
26.	Power Supply +6V	120	Group 17	
27.	Power Supply -6V	121	Group 18	
28.	Capacitor Board	128	Group 19	
29.	Fan 1, 2, 3, 4, and 5 AX 2H Fan, 115V Single Phase 400Hz Motor Series 414 YS	123 124 125 112 113	None None None None None	Vendor: Rotron Mfg Co. Hasbrouck Lane Woodstock, N.Y.
30.	Thermostat Series VE-2, Factory Set and Sealed Contact CR at 55°C.	127	None	Vendor: G.V. Controls, Inc. 101 Okner Parkway Livingston, N.J.
31.	Side-Slip Sensor angle of attack Transmitter with 15V heater	209	None	Vendor: Teledyne, Inc. P.O. Box 863 Charlottesville, Va. Synchro provided for vendor Clifton Precision Products Corp. Part No. CDH-8-A-2
32.	Detectors	211 212 213	Group 24 Group 24 Group 24	See also GEK 5020, attachment 12 of AMPD system manual GEK 5019
33.	Pitot Static Tube 852a, 115v heater 400Hz. Includes mating connector	215	None	Vendor: Rosemount Engineering Co. 4900 West 78th St. Minneapolis, Minn.
34.	Roll Frame Part No. 405-655	216	None	Vendor: Canadian Marconi Co. 2442 Trenton Ave. Montreal 16, P.2. Canada

Table 3-17. Documentation Listing (Continued)

Item No.	Title	AMPD-2 Unit No.	Index Listing	Remarks
35.	Corona Converter Assy	220 221	Group 24 Group 24	See also GEK 5023, attachment 15 of AMPD system manual GEK 5019
36.	Thermostat Series VE-2, Factory Set and Sealed Contact CR at 55°C.	217 219	None None	Vendor: G.V. Controls, Inc. 101 Okner Parkway Livingston, N.J.
37.	Temperature Probe	224	None	See page 2 item No. 7, TAS transmitter
38.	Fans 1, 2 and 3 AX 2H Fan, 115V Single Phase 400 Hz Motor series 414 YS	226 227 228	None None None	Vendor: Rotron Manufacturing Co. Hasbrouck Lane Woodstock, N.Y.
39.	Pods	—	Group 26	
40.	Functional Block Diagram	--	Group 27	
41.	Running List	—	Group 23	
42.	Control & Display Specification	--	Group 21	
43.	System Shielding	—	Group 22	
44.	Program Procedure	—	Group 28	
45.	Wing Pylon Connector (Plate-Mounted, 1PV24-31 and 4PV24-61 Inserts) Cannon 102786-0001	50P1 50J1 51P1 51J1	-- -- — —	Vendor: ITT Cannon Electric 61 Cook Hill Rd. Windsor, Conn.
46.	Map Board	--	Group 30	
47.	Ground Support Equipment	—	Group 31	
	a. Tape Reader and spooler	--	Group 31	
	b. Flight Reference system Test Kit	—	Group 31	See also appendix F of GEK 5019
	c. Analyzer Test Kit	—	Group 31	G
	d. Power Supply Test Kit	—	Group 31	A
	e. Multiplexer Test Kit	—	Group 31	B
	f. Computer Test Kit	—	Group 31	H
	g. MRI Test Kit	—	Group 31	E

Table 3-17. Documentation Listing (Continued)

Item No.	Title	AMPD-2 Unit No.	Index Listing	Remarks
47.	Ground Support Equipment			
	h. A/D and D/A converter Test Kit	—	Group 31	D
	i. Detector Test Kit	—	Group 31	I
	j. TND-4 Test Kit	—	Group 31	J
	k. Small particle detector CN	—	Group 31	K
	l. S/D Test Kit	—	Group 31	C
	m. Precise Angle Indicator CPPC P/N 42100000-1 (Modified)	—	Group 31	Vendor: Clifton Precision Product, Inc. Drexel Hill, Pa.
	n. Pod Alignment Fixture	—	Group 31	See also AMPD system manual GEK 5019, chapter 3.
	o. Computer Test Harness Modified	—	Group 31	Vendor: Canadian Marconi Co. 2442 Trenton Ave., Montreal 16, P.2., Canada
	p. Atmospheric Control Chamber	—	Group 31	
	r. Map Board Coding Device	—	Group 31	
	s. Map Board Punch Whitnes Metal Tool No. 5 Jr Hand Punch with Stand			Vendor: Whitney Metal Tool Co. Rockford, Ill.

Section 4

MAINTENANCE

4.1 SCOPE

The general maintenance philosophy for the AMPD-224 System is discussed in chapter 4. Although the major emphasis was placed on the design of the system, the maintenance concepts were developed early in the program so that a unified and integrated maintenance plan was implemented as an integral portion of the total system design.

The following paragraphs delineate the implemented maintenance concepts as contained within the operational and maintenance manuals and supported by the ground support equipment, spare and repair parts, and training programs. The concepts were initiated for the support of two AMPD-224 systems; these concepts later adapted to a single system support when the first system was lost.

4.2 MAINTENANCE CONCEPTS

The maintenance planning during the first quarter of 1967 was primarily concerned with surveying the various vendors supplying equipment to obtain recommendations for the support of their equipments. These recommendations were then combined and integrated into a overall support plan for the total system and its integral parts and implemented as a portion of the total system design requirements.

The general troubleshooting philosophy is basically as follows: A common approach to all system elements to essentially provide the ability to rapidly determine the location of a failed black box (system unit) and to replace it with a known good unit. Maintenance of the failed unit is then performed at a maintenance depot, rather than on the system.

A complete system of Functional Block Diagrams (FBD's) was developed to allow sufficient understanding of each units function(s) to allow determination of the adequacy of each input and output signal and to specify breakout points within the system for monitoring the functions. The incorporation of the system junction box in the baggage compartment allows for maximum monitoring capabilities for signals flowing between pods and between a pod and the aircraft. The basic FBD approach provides self-instruction concurrent with troubleshooting so that proficiency increases with experience.

To further implement this approach, a complete set of System J-Box signal specifications was generated to allow comparison of the actual signal with the corresponding specification at each of the several hundred J-Box locations. The description is sufficient to allow proper association with the appropriate subsystem unit and its signal which may be out of specification. Both the System J-Box signal specification and the FBD package are contained within the maintenance section of GEK-5019, the 224 AMPD System Operational and Maintenance Manual. In addition to the above, sixteen special procedures were prepared and incorporated into the system manual for calibration and test of the system.

A schedule for periodic system and subsystem maintenance was generated to ensure continuous system operation within the specified accuracies. The schedule makes reference to the appropriate manual which contains the procedure to be performed. Adherance to this schedule is required to ensure accurate, trouble-free operation.

The requirement for determining system readiness prior to a mission flight is met by the successful performance of the Pre-Flight Checkout Procedures. This set of procedures provides a gross quick check of the total AMPD-224 system and assumes that periodic maintenance has been performed as scheduled. Post Flight Maintenance Services contain the procedures which must be performed following a mission flight.

All of the preceding procedures with the required supporting material such as spare and repair parts lists, removal and replacement procedures are contained in the 224 System Manual.

The maintenance of the subsystem units is, in general, to be performed at a maintenance depot. The maintenance depot is defined for each unit uniquely and is in actuality a function of the experience and training of the on-site service personnel. The maintenance facility for both the system and the subsystem levels is the maintenance van which is a U.S. Army M292 van into which was built the necessary benches, storage bins, files, and power units.

When not expanded, the van inside dimensions are approximately 17 x 8 feet, and expanded are approximately 17 x 14 feet. It contains built-in florescent ceiling lights (24 15-watt tubes); a 37,000 BTU air conditioner; two gasoline heaters; telephone wiring, and 120/208-volt power service.

The original van configuration requirement is shown in the layout in figure 4-1. When the M292 became available, the facilities design was modified to be compatible with it.

The facility is stocked with the necessary spare and repair parts and ground support equipment to perform the required test and maintenance of system units. All units can be tested in the van to determine their status. When it has been confirmed that a unit has failed, it is returned to a depot for repair. In some cases, the M292 van is the depot as in the case of the detectors and converters. In other cases, the manufacturer's factory is the depot as is the case with the Mk 12 computer. There are many units which fall in between these two limits. That is, some maintenance can be performed in the van before it is sent back to the factory. For example, much maintenance has been accomplished on the AN/ASN-64 Navigator in the van; however, beyond a given point the units are shipped back to Canadian Marconi for more complete maintenance and calibration.

In summary, the basic maintenance philosophy which was developed early in the program, has been implemented but continues to be modified as more experience is gained with both the system and the maintenance facilities.

4.3 OPERATIONAL AND MAINTENANCE MANUALS

The System Operational and Maintnance Manual GEK-5019 performs three basic functions: it presents the physical and functional description on a system level; it is a training document and reference manual for the operation of the system; it delineates the maintenance policy and provides or references the maintenance (preflight, post-flight, periodic, and troubleshooting) procedures.

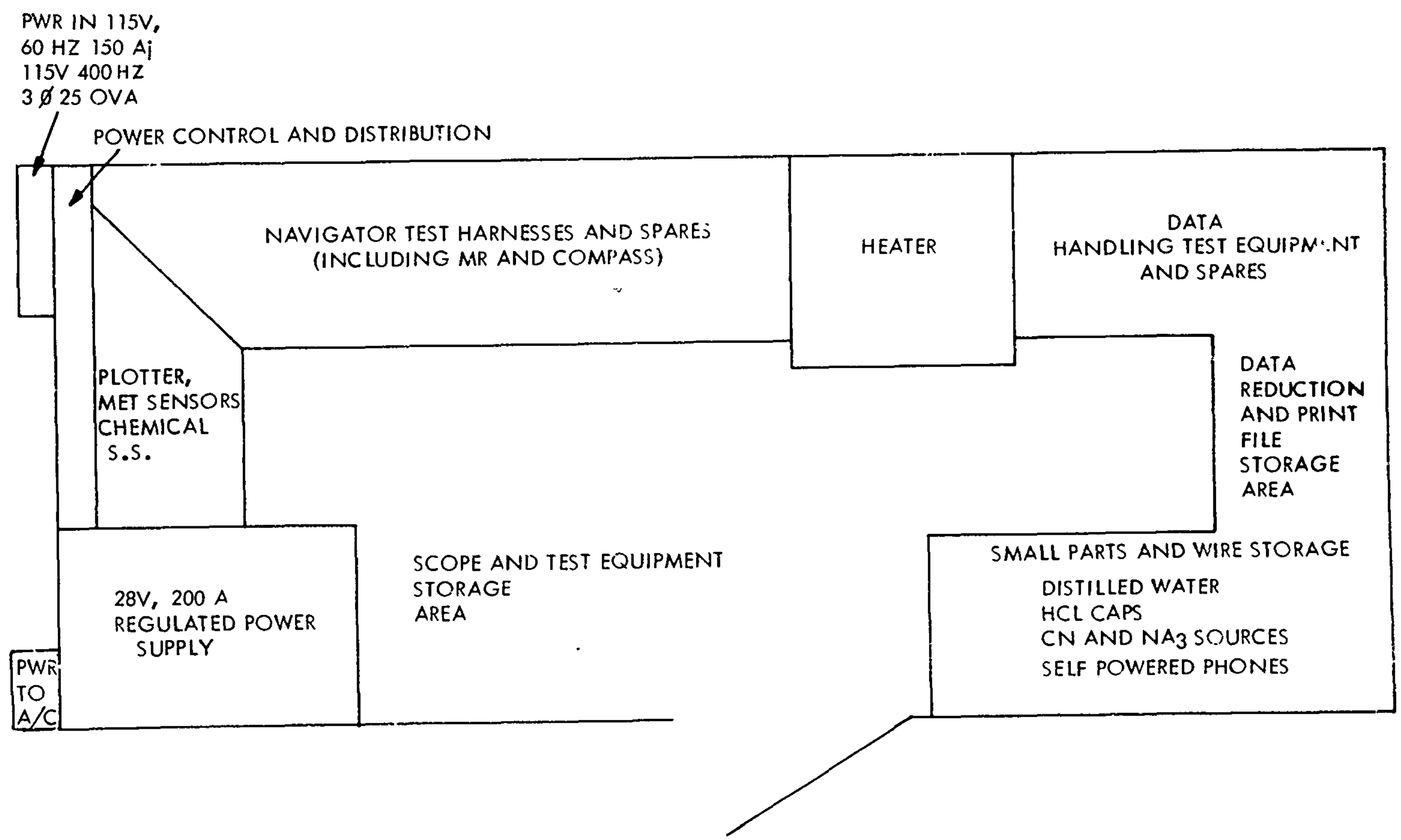


Figure 4-1. Maintenance Van Layout.

The ground rules that were adopted with respect to GEK-5019 are as follows:

1. The publication will be addressed to system level of operation and maintenance procedures. Specific maintenance procedural instruction will be limited to isolation of system faults to a particular black box and to procedures for substitution of a serviceable box for the faulty box.

2. The General Electric Company technical publication will be accompanied by equipment manuals prepared by the vendors who have produced the various components of the system. The package of vendor equipment manuals will include General Electric Company manuals pertaining to GE-produced equipments, such as the detector.

3. Repair of faulty black boxes will be accomplished to the extent that vendor equipment manuals accompanying the system manual provide information to do so.

4. Presentation of equipment operation and maintenance instructions in the system manual will be keyed to instructions contained in three equipment operation tables: Energize System, In-Flight Operation, and Deenergize System.

   a. Each of these tables is organized to present instructions in logical sequence with each step specifying the crew member who performs the step, the action required, the control to be handled and its location, the desired indication (lamp, meter, or the like), and the adjustment to be performed to obtain the desired indication.

   b. In those cases in which the desired indication cannot be obtained by adjustment, adjustment instructions require referral to the Trouble Isolation Procedures table to trace the fault to a specific component of the system.

   c. After identification of the black box in which the system fault lies, the Installation Procedures tables are used to remove and replace the faulty box, with a serviceable box from the store of spares. Energizing procedures are once again initiated and the mission flight can be undertaken with minimum delay.

   d. Further trouble isolation of the fault within the faulty box is accomplished by use of instructions provided in the vendor equipment manual provided for that specific item of equipment. The box is returned to the shelf for future use after it is returned to serviceable condition.

It is anticipated that the vendor equipment manuals and the supporting General Electric Company equipment manuals will become a part of GEK-5019 as attachments and are referred in the appropriate GEK-5019 procedures as required. The General Electric Company manuals are as follows:

GEK-5019—Aircraft Mounted Personnel Detector (Chemical) System (224AMPD), Operation and Organizational Maintenance.

GEK-5020—Detector, Condensation Nuclei (224AMPD), Organizational Maintenance.

GEK-5021—Multiplexer, Digital (224AMPD) Organizational Maintenance

GEK-5022—Analyzer, Detector Signal (224AMPD), Organizational Maintenance

The vendor equipment manuals are as follows:

Canadian Marconi Co., Ltd.	AN/ASN-64 Doppler Radar Navigation Set, Technical Manual
Kennedy Co.	Recorder, Operation and Maintenance Manual
Astro Electronics	Synchro-to-Digital Converter, Maintenance Manual
Sperry Gyroscope	Mk 12 Computer, Overhaul Manual
General Electric Co. (West Lynn)	AN/ASN-76 Flight Reference System, Operation and Maintenance Manual
Meteorology Research, Inc.	IM-82 Instruction Manual, Universal Turbulence Indicator with True Air Speed and Temperature Model 2009P
Honeywell, Inc.	M-135 Micro Pac Operation and Maintenance.
US Army	TM 11-5841-264-12 Maintenance Kit, Electronic Equipment, MK 866/ASN-64 Organizational Maintenance Manual
US Army	TM 11-584-1265-12 Test Facilities Kit MK 864/APN-168, Organizational Maintenance Manual
US Army	TM 11-5841-266-12 Test Facilities Kit MK 865/AYA-3, Organizational Maintenance Manuual

The special ground support equipment (paragraph 4.4) maintenance and operational procedures are included in GEK 5019 as appendices. These include primarily the GE-built van-mounted test equipment. As the various portions of GEK 5019 were generated by engineering, the drafts were submitted to the field service personnel for their early use and comments so as to provide as early, complete and accurate a manual as was possible in a minimum amount of time. The first draft release to the field was in August 1968.

4.4 GROUND SUPPORT EQUIPMENT

The definition of ground support equipment requirements needed to implement the maintenance plan began in mid-1967. The mechanical pod handling concepts were developed early and a study on pod handling published in May 1967 is included as Appendix G in this report.

Several different categories of ground support equipment were required. Some equipment fell into the category of standard commercial test equipment; oscilloscopes, multimeters, pulse generators, for example. Several pieces of special commercial equipment such as a recorder test kit, ASN-64 computer, and doppler test harnesses, etc., were required. Loral built a special test kit for the plotter. Special test kits which were not commercially available were designed and fabricated by GEOS.

Ground Support Equipment planning and acquisition went through many changes and modifications. Many planning sessions were held and lists generated. The final ground support equipment requirements are contained in Chapter 5 of GEK 5019.

4.5 SPARE PARTS

Spare Parts are those system units which can be replaced within the system. In general, the spare parts make up a third system. However, some components such as the antenna were felt to be reliable enough not to require sparing. The spare parts are maintained by the depot and checked out in the maintenance van to ensure that they are ready for system installation. When a system failure occurs, the failed unit is replaced with a spare unit. The required spare parts are listed in Chapter 6 of GEK-5019.

4.6 REPAIR PARTS

The repair parts are those parts which are used to repair the failed units in the maintenance van. As the field service personnel become familiar with maintenance of the system units through experience and vendor training courses, more maintenance will be performed in the van. The repair parts will be used for these repairs.

The required repair parts are listed in chapter 6 of GEK-5019.

4.7 TRAINING COURSES

Several vendors training courses are required to provide maintenance personnel with information necessary to repair system units. In Septemper, 1967 GEOS personnel attended a course on the AN/ASN-64 Navigational Set. This course in particular has proved to be of great value.

In April 1968, Astrosystems conducted a training course on the S/D Converter for GEOS personnel. Loral Electronics sent a representative to Aberdeen to give a course on the plotter to GEOS people then. Other courses are contemplated prior to deployment. Instruction on the Mk 12 Computer is of prime importance due to the lack of Sperry Maintenance support at overseas locations.

4.8 PREDEPLOYMENT CONSIDERATIONS

Prior to deployment, there are several items which should be accomplished to ensure complete support for the system. Although the following list is by no means complete, it does represent a significant area of activity and may be used as the basis for further consideration.

1. Certified Tape Supply
2. Tape cartridge—correct
3. Set up Hanger Queen for program change checkout
4. Investigate tape printout facilities—trial runs—possible reprograming
5. Determine data analysis approach—establish facility—analysis required for mission evaluation and for equipment evaluation
6. Maintain system operation and maintenance manual
7. Revise analyzer converter and detector and maintenance manual

8. Incorporate reliability modifications into navigator

9. Establish Navigator maintenance philosophy, and implement

10. Obtain vendor item manuals

11. Correct detector optical block corrosion problem

12. Investigate and correct tape recorder temperature problem

13. Procure high temperature magnetic tape

14. Field test OV-1 system to determine new math model input ranges—reprogram

15. Sperry maintenance course

16. Investigate field tape—handling problems

17. Obtain supply of corona points and wicks

18. Develop new flight plan sheet and obtain a supply of same

19. Investigate power availability for van at site

20. Establish a failed component return procedure and implement

21. Obtain supply of maps for surveillance area

22. Evaluate mapboard and plotter pen procedures and implement

23. Obtain all repair parts

24. Arrange for compass swing following reinstallation

25. Obtain special packing for 2 or 3 gyros

26. Resupply miscellaneous spare parts—resistors, capicator, hardware, tubing

27. Obtain supply of distilled water and acid
28. Conduct military operators training school
29. Purchase 200-amp rectifier

30. Pack van, test gear, and pods

31. MRI heat problem investigation

32. Obtain Test Equipment (some presently being rented; some on loan from GEOD and and LWL, some never procured)
33. Install DRO Power Supply noise kit
34. Overhaul navigational sets
35. Design documentation maintenance and upgrading

Section 5

EQUIPMENT AND SYSTEM ANALYSIS

5.1 SCOPE

This chapter contains significant equipment and system analysis studies performed during the AMPD-224, Phase IV effort.

5.2 SYSTEM HUMAN FACTORS AND SAFETY STUDY

5.2.1 Purpose:

1. To assure the department Product Safety Representative and the Program Manager that the Project 224 system is reasonably safe to operate and maintain and that it does not constitute a major hazard to personnel when operated in conjunction with other associated equipment.

2. To evaluate the equipment design in terms of its interface with the operator maintainer.

3. To provide two levels of recommendation.

   a. Where design deficiencies are judged to be critical and fixes are necessary.

   b. Where deficiencies do not significantly affect the operation or maintenance of the system and such fixes would be considered product improvement.

5.2.2 Scope:

The scope of the evaluation program includes the entire Project AMPD-224 equipment, its immediate operating environment, and the currently available operating and maintenance instructions.

5.2.3 Implementation:

1. The safety evaluation was conducted based primarily on the Product Safety Design Standard (TM 68-01), the product safety check-list, and the previous safety analysis conducted by Reliability Engineering.

   The evaluation will be concerned with the design of the equipment and its safety interface with operators and maintenance personnel, and also with currently available operational and maintenance procedures.

2. The Human Factors evaluation was based on applicable portions of Mil-Std-803A "Human Engineering Design Criteria for Aerospace Systems and Equipments" in conjunction with an appropriate checklist. Its prime concern was the clarity of information

presented to the operator, ease of operation, and generally the maintainability of the system equipment.

This evaluation was conducted on the AMPD-224 system installed in JOV1-B, tail number 92627, in accordance with the above outline.

5.2.4 Product Safety Evaluation

The Product Safety evaluation was based upon TM-68-01, using the Product Safety Checklist PO 6036 (para 5.2.6) as a guide. No conditions were found which were deemed major safety hazards to the operator or maintainer; however, the system was found to deviate from the checklist as follows:

1. Weight and center of gravity of the pods are not designated (ref TM 68-01; pg 10, para A2).

2. Recorder fans are exposed and do not have safety covers (ref TM 68-01; pg 3, para B8).

3. Equipment incorporates a hygroscopic synthetic foam material for shock isolation bases, flexible ducts, etc. (ref TM 68-01; pg 8, para A16).

4. Interlocks are not provided where voltages exceed 70 volts rms (ref TM 68-01; pg 4, para A3).

5.2.5 Safety Recommendations

1. Mandatory Fixes

   a. Weight/Center of Gravity—Because the pods will be manhandled, both the weight and center of gravity must be designated on the pods.

   b. Exposed Fans—Guards must be installed on recorder fans or fans must be relocated or redesigned to preclude any possibility of personnel contact during maintenance procedures.

2. Recommended Fix

   a. Hygroscopic Material—The use of hygroscopic material is deemed to be nonhazardous to personnel; however, its potential affect upon equipment suggest that, from a design viewpoint, its use be discontinued.

3. Allowable Deviation

   a. The incorporation of interlocks, although recommended in TM 68-01, is not considered requisite to personnel safety on the 224 system due to package configuration and general accessibility of components within the various system boxes.

5.2.6 Human Factors Evaluation

The Human Factors evaluation was based on applicable portions of Mil-Std-803A (Human Engineering Design Criteria for Aerospace Systems and Equipment) in conjunction with a checklist (para 5.2.6) developed to evaluate the equipment interface with the operator/maintainer. The following recommendations are submitted for consideration of incorporation into any follow-on 224 systems.

1. Additional service loop should be provided on cockpit interconnecting electrical harnesses to ease equipment installation.

2. Panel indicator lights should be provided with variable control for the purpose of reducing light intensity. At present, the high intensity of panel lights presents possible windshield glare problems during night flights.

3. The time-of-day input/readout switches located on the digital data panel appear not to represent the best way to accomplish the intended purpose. An investigation of drum counter/thumbwheel switch devices could result in less panel space providing a more readily interpreted readout.

4. Pods do not appear to be firmly attached to aircraft, a condition that, should additional looseness develop, could cause erratic equipment behavior.

NOTE: The Human Engineering Checklist and the Product Safety Checklist (PO 6036) follow.

5.3 HUMAN FACTORS PLOTTER STUDY

The following study was performed in October and November, 1966, in order to define the important characteristics for the plotter for the AMPD-224 system. The study was used as an aid in evaluating the adequacy of the Phase II plotter to perform the required mission. Areas investigated included usefulness of various map scales, the need for permanent marking of aircraft track and target positions, the need for map overlap, the number and types of controls, the methods and accuracies of updating aircraft positions.

The study was performed from a Human Factors point of view, because the plotter becomes the primary operator system interface device. It displays, in real time, the total operational situation. The study follows Product Safety Checklist (PO 6036).

5.4 DETECTOR—CONVERTER TRANSIENT RESPONSE STUDIES

The following four studies on detector-converter transient response were generated during the Phase IV program by A. M. VanBlarcom, Consulting Systems Engineer, Electromechanical Equipment Operation, GEOS. The first is a study of a continuous flow system and derived some basic parameters for the second report. The second report provides a study of the Phase II system and determines changes and modifications needed in the Phase IV design.

The third report reports tests on the Phase IV detector-converter combination and considers physical parameter effects including valve slot size, humidifier design, length and diameter of inlet tubing, and block diameter passage sizes. The graphs which follow this report summarize the results.

The fourth report is a study of the transient responses to 5- and 10-cycle detectors, with and without converters.

All four studies follow the Human Factors Plotter Study.

HUMAN ENGINEERING CHECK LIST

I. CONTROLS

1. Are controls distributed so that no limb is overburdened?

2. Does the control movement conform with the movement of the controlled display or equipment?

3. Are the controls labeled by means of arrows and appropriate legends?

4. Is the label either on the control or immediately adjacent to it (above, if possible)?

5. Are red, amber, green, white, or blue the only colors used for coding?

6. Are controls located so that the operator is not likely to hit or move it accidentally in normal sequence of control movements?

7. Is there a guard for those toggle switches susceptible to accidental activation, which is considered serious?

A. Controls, Rotary Selector Switch

   1. Have stops been provided at the beginning and end of the range of control positions, if switch should not be operated beyond the end positions or specified limits?

   2. Does clockwise movement of the control increase the setting value?

   3. Is the pointer knob a type with a tapered tip?

B. General

   1. Has a single visual area been used?

   2. (Compactness) Have extended displays been avoided?

   3. (Priority) Have the important and frequently used displays been located nearest the normal line of sight?

C. Display Location

1. Is the location of the instruments in reference to other instruments satisfactory?

2. Is the display located normal to the line of vision?

D. Displays, Counters

1. Is the counter used to present quantitative data?

2. Is the space between numerals more than 1/2 the numeral width?

3. Is the counter mounted as close to the panel surface as possible to maximize viewing angle and minimize parallax and shadows?

4. Is counter mounted horizontally and not vertically?

5. Does the counter read left to right?

E. Displays, Signal Lights

1. Are warning lights for critical functions within 30 degrees of the normal line of sight?

2. Has consideration been given to provide two brightnesses, one for daylight and one for night use?

II. ENVIRONMENT

1. Do personnel exposed to noise levels exceeding 135 db always wear equipment to reduce the noise entering the ear canal?

2. Is stationing of personnel in areas where the noise level exceeds 95 db for prolonged periods avoided?

3. Are noise levels in excess of 75 db avoided where verbal communication is necessary?

4. Are noxious gasses in significant levels in the operator area?

5. Are equipment finishes glare-free?

6. Are control panel finishes dark enough in color to minimize eye fatigue from reflection during extended use in bright sunlight?

7. Does vibration effect operators in performance of their duties?

8. Are sharp gradients in illumination ratios of 10:1 or greater avoided?

III. PERSONNEL OPERATIONS

1. Has care been taken that operators are not required to read a number of indicator lights in order to receive a quantitative message?

2. If there is an auditory display; is the auditory signal easily discriminable from the ambient noise?

3. Is the speed with which information can be secured satisfactory?

4. Are there too many procedures to be accomplished simultaneously?

5. Are there too many meticulous tasks performed under difficult environmental conditions?

6. Are there tasks that require extremely accurate judgment?

7. Is equipment designed so that it may be operated by personnel wearing protective clothing?

8. Are means employed for minimizing exposure to corrosive agents?

9. Does the occurrence of the communication follow procedures?

10. Was the correct communication line or channel used?

IV. ACCESSIBILITY AND HANDLING

1. Are components of the plug-in type?

2. Can components be replaced easily and rapidly?

3. Were component accesses designed with consideration given to frequently use?

4. Is it physically impossible to install a wrong unit?

5. Are test points, meter jacks, probe points, connectors, etc., located conveniently?

6. Are access points well labeled?

7. Are access doors either removable or self-supporting?

8. Is the amount of space, required for normal and replacement of all parts, adequate with respect to the physical position of the maintenance man, so that no extended stretching or other unsuitable positions are required?

9. Is handling of the parts easy, during removal and replacement operations, due to proper handles and shape, size, and weight of the parts?

10. Are assemblies and parts removable without the use of special tools and/or excessive amount of tools?

11. Is the amount of space, required for removal and replacement operations, adequate with respect to the method of handling the parts (lifting, pulling, sliding, turning, etc.)?

12. Is the required auxiliary equipment, such as work platforms and ladders, adequate for maintenance tasks?

13. Are fuses and circuit breakers adequately identified and located for easy and quick replacement or repair?

14. Is the variety of tools required at a minimum?

15. Are tools required adequately insulated for safety?

16. Is a minimum number of turns required of bolts and fasteners?

17. Are items to be lifted less than 40 pounds (arm lifting without aid of legs)?

V. CODING FOR IDENTIFICATION

1. Are electrical cables, circuits, terminal plugs and receptacles color-coded and permanently marked?

2. Are all piping, tubing, and hosing lines for liquid, gas, steam, etc., clearly and unambiguously labeled and/or color coded as to contents, pressures, heat, cold, voltages, and any specific hazard properties?

3. Are labels in view and not hidden by parts?

4. Is the meaning of colors explicitly stated in printed job instructions?

5. Are test points and lubrication points plainly identified?

VI. CABLES AND CONNECTORS

1. Are connectors located properly for easy access and maintenance?

2. Are aligning pins provided whenever required?

3. Are "quick-disconnect" plugs used wherever possible?

4. Is the equipment designed so that receptacles are "hot" and the plugs are "cold" when disconnected?

5. Are plugs and receptacles provided for connecting cables to equipment units rather than pigtailing the cables to the units?

6. Are cables long enough so that each functioning unit can be checked in a convenient place?

7. Are wires and cables that run through holes in metal partition protected by mechanical grommets or other acceptable means?

8. Are connectors and cables properly labeled and easily distinguishable?

9. Are plugs designed so that it is impossible to insert any plug in the wrong receptacle?

VII. SAFETY AND HAZARDS

1. Do switches and controls which initiate hazardous operations, require the prior operation of removing warning shield or locking device?

2. Are guards provided on all moving parts of machinery and transmission equipment including pulleys, belts, gears, blades, etc., in which personnel may become injured?

3. Are all high pressure, high voltage, explosive, fire and other hazardous maintenance areas of facilities marked with warning signs or other identification?

4. Are all electrical outlets and junction boxes properly marked as to high voltage contained therein?

5. When maintenance is being performed on electrical systems, are lockouts or other safety precautions used to prevent inadvertent operation of the system?

VIII. WORK SPACE

1. Are the displays, controls, etc., mounted and/or inclined properly for normal continuous seated operations?

PRODUCT SAFETY CHECKLIST

PROGRAM 224 EQUIPMENT [illegible]

TYPE REVIEW:

PRELIMINARY SAFETY ANALYSIS	☐	DETAIL DESIGN SAFETY ANALYSIS	☐
SYSTEMS DESIGN SAFETY ANALYSIS	☐	OPERATING SAFETY ANALYSIS	☐
EQUIPMENT DESIGN SAFETY ANALYSIS	☐	OTHER ______	☐

REVIEW PERFORMED BY (Give Name and Unit) [illegible] - HFS

DATE [illegible] May 19[illegible]

This checklist is to be used in conjunction with TECH MEMO 68-01, PRODUCT SAFETY DESIGN STANDARD and the safety design specification.

DIRECTIONS:

Review all items as directed in the safety design specification.

All items on checklist must be checked. Indicate N/A only if an item is not required by the safety design specification. Indicate either YES or NO for all other items.

All items with a NO indication are to be listed as ACTION ITEMS. All ACTION ITEMS are to be fully clarified including definition of hazard, required corrective action, responsible individual, and completion schedule. When corrective action is completed the ACTION ITEM will be marked CORRECTED and dated.

This PRODUCT SAFETY CHECKLIST is to be retained as a safety program record.

SAFETY CHECKLIST

. WORK AREA HAZARDS	N/A	YES	NO action item
1. Alarms are provided to warn against fire, asphyxiating gas, or radiation.	✓		
2. Emergency doors are readily accessible, unobstructed, quick opening, and operable by a single motion of hand or foot.	✓		

P. O. 6036(4-68)

Item	N/A	YES	NO action item
3. Automatic emergency doors or barriers have manually operated personnel exits.	✓		
4. Obstruction-free work space is provided around manual maintenance areas.	✓		
5. Adequate illumination is provided for stairways, service areas, warning signs, etc.	✓		
6. Warning placards are displayed where toxic, volatile or explosive material is stored, handled, or used.	✓		
7. First aid equipment is readily available where toxic materials will be stored, handled, or used.	✓		
8. Fire alarm and extinguishing equipment is readily available where volatile or explosive material will be stored, handled, or used.	✓		
9. Ventilation and exhaust equipment is provided where toxic, volatile or explosive material will be stored, handled, or used.	✓		
10. Comprehensive handling procedures and special handling equipment are provided where toxic materials are used in cleaning or maintenance operations.	✓		

B. EQUIPMENT HAZARDS

Item	N/A	YES	NO action item
1. Hazardous operation controls are equipped with locking or interlocking devices.	✓		
2. Moving equipment controls are equipped with dead-man releases.	✓		
3. Control-activated warning devices are provided where hazardous operations dictate.	✓		
4. Access to equipment can be achieved without danger from electrical charge, heat, moving parts, chemical contamination, radiation, or other sources.		✓	
5. Doors and covers exposing dangerous ~~mechanical or~~ electrical components activate internal lights.			✓
6. Doors and covers exposing dangerous mechanical components are provided with external warning labels.	✓		

P.O. 6036(4-68)

Item	N/A	YES	NO action item
7. Doors are provided with hold open stops.	✓		
8. Handles or provision for lifting facilities are provided for units weighing over 10 lbs.	✓		
9. Lift points of equipment are marked when applicable.			✓
10. Weight and center of gravity of equipment are marked when applicable.		✓	
11. Edges and corners are rounded to minimum radius of .01 inch and .50 inch respectively.		✓	
12. Fuel service equipments are provided with automatic shut-off devices.	✓		
13. High temperature surfaces are shielded.	✓		
14. Fans, blowers, and moving equipment are made safe by location, use of guards, and/or warning devices.		✓	
15. High pressure (vacuum) lines or vessels are provided with shields or guards.	✓		
16. Material used on equipment is not ~~toxic~~, hygroscopic (moisture absorbing), ~~combustible or fungus supporting.~~			✓
17. Pipe, hose, or tube lines for liquids, gas, or steam are labeled for contents, pressure, and temperature as necessary.	✓		
18. Self-locking devices are provided to prevent platform movement.	✓		
19. Outriggers are provided where required for platform stability.	✓		
20. Guardrails, safety bars, or chains are provided across stairways, equipment accessways, etc., as required.	✓		
21. Safety mesh or screen is affixed to the underside of open-grating platforms as protection to men or equipment beneath.	✓		
22. Sufficient work room is provided to allow use of proper maintenance equipment.		✓	

C. ELECTRICAL HAZARDS

Item	N/A	YES	NO action item
1. Equipment containing voltages in excess of 24 volts is safety designed.		✓	

		N/A	YES	NO action item
2.	Equipment containing voltages in excess of 70 volts rms is provided with interlocks.			✓
3.	Voltages in excess of 70 volts rms, but less than 200 volts rms, are isolated with guards or barriers.		✓	
4.	Voltages in excess of 200 volts rms are isolated with enclosures.	✓		
5.	Wave guides, ~~high frequency cables, and insulated high-voltage cables~~ are protected by guards or other devices.			
6.	Interlock disable devices activate warning lights.	✓		
7.	Interlock disable devices are automatically reset when equipment is returned to normal mode (i.e. door is shut).		✓	
8.	Plugs and receptacles are wired so that receptacles are "hot" and plugs "cold" when disconnected.		✓	
9.	External metal parts of equipment are at ground potential.		✓	
10.	Antenna and transmission line terminals are at ground potential.	✓		
11.	Portable tools and equipment are provided with three wire plugs or other suitable automatic grounding devices.	✓		
12.	Grounding rods as well as storage and connection provisions are provided with transmitting equipment.	✓		
13.	Test points are accessible and are located away from dangerous components.		✓	
14.	Voltage dividers are provided with test points for measuring voltages above 1,000 volts rms.	✓		
15.	Internal controls are accessible and are located away from dangerous or delicate components.			
16.	High energy capacitors are provided with discharge devices and terminals are not exposed to contact.			✓
17.	Preventive maintenance diagrams and procedures are labeled CAUTION where necessary to denote a potentially hazardous operation/procedure.		✓	
18.	Warning plates are located near exposed contacts or terminals having potentials exceeding 200 volts rms.	✓		
19.	Radiation is controlled through safety design to provide adequate protection against microwave and ionization hazards.	✓		
20.	Cathode ray tubes are provided with protection from implosion and x-ray radiation.	✓		

P.O. 6036(4-68)

PRODUCT SAFETY CHECKLIST
ACTION ITEMS

All checklist items with a NO indication must appear as ACTION ITEMS.

Give ACTION ITEM number, definition of hazard, required corrective action, responsible individual, and completion schedule.

When corrective action is completed, the ACTION ITEM must be marked CORRECTED and dated.

Attach additional sheets as required.

(See HFE [illegible] from E. W. [illegible] to R. [illegible] 31 [illegible]
Subject: Project 224 Human Factors/Product Safety Evaluation)

P.O. 6036(4-68)

HFE File # HF-6E-1

HUMAN FACTORS PROJECT 224 PLOTTER STUDY

SUBMITTED TO

A. M. Van Blarcom

14 November 1966

By:

E. W. Dalzell, Jr.

E. W. Dalzell, Jr.
Reliability & Human Factors Engr'g.

November 14, 1966

SUBJECT: Human Factors Project 224 Plotter Study

I. PRELIMINARY

The primary Human Factors interest in the 224 plotter is how best to assure that:

1. Data collected is meaningful by assuring that proper levels of accuracy between sensor, plotter and map scale are observed.
2. Data collecting device is compatible with scalar requirements, operational conditions, information requirements, and human sensory interpretation.

It is not the intent of this report to recommend a particular type or brand of plotter, but rather to define those characteristics by which any selection should be measured. The project 224 plotter has a base requirement of maximum flexibility, a condition which precludes firm "this and no other" kinds of recommendations. The following parameters have been established as the basis for the design decisions and recommendations which appear in this report.

1. Plotter use requirements:
   - Search - broad area coverage.
   - Locate - small area coverage.
   - Navigate (optional) - aircraft navigation only without sensor operating.
2. Aircraft speed - 140 knots
3. Aircraft altitude - 100 to 300 ft.
4. Mission Time - Not limited by system capability; however, normal mission time is estimated between 2 and 3 hours.
5. Day/Night Use - Not limited by system capability; however, it is anticipated that night use will be minimal.

6. Operator - Plotter will be operated by co-pilot. It is assumed that operator will have other duties during a mission but that during system operation he will devote full time to monitoring the plotter. The operator will be trained in the use of the plotter and will be adequately familiar with system operating characteristics and philosophy.
7. Operating Environment - High noise level, moderate to high vibration level, moderate to heavy undulatory movement.
8. Sensor Error - It is assumed that the sensor can detect a signal source within, but not closer than, 700 meters. For the purpose of this report a sensor error of 700 meters is considered to be a constant.
9. Maximum Plotter Display Size - It is assumed that aircraft space limitations disallow a plotter display area larger than 7 inches square.

II. DEFINITIONS

For the purpose of this report, the following definitions shall apply:

Map Scale - Ratio of map distance to land distance. A 1:100,000 scale map indicates that 1 inch of map surface represents 100,000 inches of land distance. The comparative terms large scale and small scale are applied in their common usage: i.e. small scale means small ratio; large scale means, large ratio (1:50,000 is a smaller scale than 1:250,000 scale).

Adjacent Map - Adjacent Map is always the same scale as the map in the plotter and is a non-redundant (not overlapping) continuation of the area being plotted.

Alternate Map - Alternate map is always the same scale as the map in the plotter and overlaps one quadrant of the map being plotted.

Equivalent Map - Equivalent Map always refers to a map of a different scale than that which is in the plotter and always refers to a map of the area directly under the pen, i.e. a larger or smaller scale map of the area being plotted.

Plotter Error - Inherent inaccuracy of the map plotter. Plotter error is a characteristic of design and cannot be corrected or reduced by calibration.

Source Location - That point on the ground from which a detectable signal emanates.

Interrupt Period - The term "interrupt period" is used with reference to time or map surface distance and represents either that time or map surface distance that the pen is not in contact with the map surface. A map change or a pen change, for example, would cause an interrupt period.

Map Capacity - The amount of map stored and automatically indexed in the map plotter.

III. MAP/PLOTTER INTERFACE

The following features represent the map/plotter interface and are responsible for the amount and quality of information acquired. A selected combination of these variables is necessary to assure the high flexibility and information gathering accuracy required of the system.

A. TWO VARIABLE FACTORS - Map scale and Plotter Error.

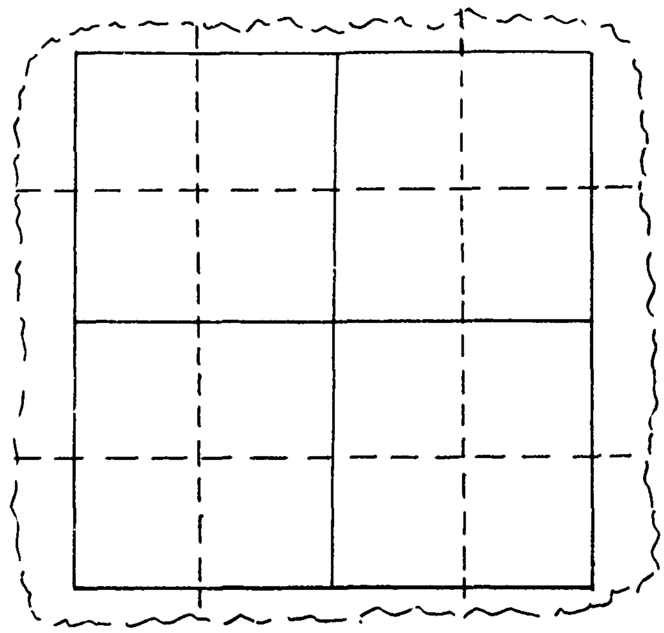
1. Map Scale - The optimum scale for operational use is the largest scale which provides the required degree of geographical identification. Scales smaller than required for geographical identification reduce the amount of land area that can be displayed in any given size plotter. Source location plot error becomes greater as the map scale is increased; therefore, depending upon the source location accuracy required, the map scale selected for a mission will be qualified by the accuracy of the plotter (see figure 1). The map scale that offers the best compromise for broad area and small area coverage (search and locate) and is generally available is 1:100,000; however, no one map will adequately meet all anticipated mission requirements. Map Scales 1:50,000 and 1:250,000 used in combination give high flexibility on a search and locate basis; however, the 1:50,000 scale is of minimum search value when used alone (4.8 nautical miles on 7 inch screen). Map Scales 1:100,000 and 1:250,000 used in combination give high flexibility on a search and locate basis and, since sufficient land area is displayed by either map on a small display screen (9.6 nautical miles for 1:100,000 and 24 nautical miles for 1:250,000 on 7 inch screen), both maps can be used alone. It is recommended that a three scale capability be incorporated in the map plotter. Such an arrangement must provide for automatic equivalent map selection.

2. Plotter Error - Source location error, on a worse case basis, is the sum of the sensor error and the land distance error of the plotter for the largest map scale that meets the particular mission interpretation requirements. Obviously, the choice of map scale cannot be made on

geographical identification factors alone, but must be made in consideration of how adequately the source location plot can meet source location requirements of the mission. Source location plot error and map scale are directly proportional; as map scale becomes larger the source location error increases. A 10:1 accuracy ratio between plotter and sensor on a 1:50,000 map becomes a 2:1 accuracy ratio on a 1:250,000 map. It is of no minor significance that a plotter with a 1/16 inch error gives the same source location accuracy on a 1:50,000 scale map that a 1/32 inch plotter error gives on a 1:100,000 scale map. Plotter error greater than 1/32 inch is undesirable and error in excess of 1/16 inch must be considered unacceptable.

B. MAP CAPACITY - Map capacity is a function of the size of the display area and the mechanical storage/display mechanism employed by the plotter. The optimum situation would be a map scale/plotter capacity combination, i.e. "under glass" capacity, that would require no map change during an entire mission. Recognizing that map change downtime under combat conditions represents a critical situation, the advantages of large map capacity are self evident provided that when maps must be changed, the operation is rapid, positive, and requires no special tools. It is important that the system have the capability to store and plot all information received (sensor detected signals and course plot) during an interrupt period. Such a capability would require accelerating the pen after an interrupt period until it is again "on course" with the aircraft.

C. MAP QUADRANT OVERLAP - In the event that an area under surveillance is located at an extreme point on a map section, it could require as many as four maps to make a complete serial survey of a relatively small land area. For this reason, it is recommended that two complete sets of maps for each scale used be employed, utilizing a quadrant overlap between the two sets.



D. MAP MARGIN OVERLAP - A map margin overlap provides no practical advantage over the quadrant overlap technique but has the serious disadvantage of reducing the amount of non-redundant map available for display. The use of a map margin technique is non recommended.

E. MAP OVERLAY - A plastic or mylar overlay material applied to the face of a map will allow re-use and at the same time protect the surface from dirt and stains which might otherwise result from handling. A map overlay is a highly desirable feature and should be used. Overlay material is somewhat of a problem with maps which are stored on rolls, as the overlay thickness will reduce the amount of map that can be contained on a fixed size roll. Also, overlay on roll type maps tends to stretch to the contour of the roll which causes ridges when the map is laid flat. It is, therefore, recommended that the feasibility of using a spray type plastic coating be investigated before any selections of overlay material are made.

F. MAP ORIENTATION - Unless the aircraft is always headed in the same direction, map orientation to true direction is of no value. Because the aircraft will be continually changing direction a north oriented (north always at the top of plotter) map/plotter relationship is recommended.

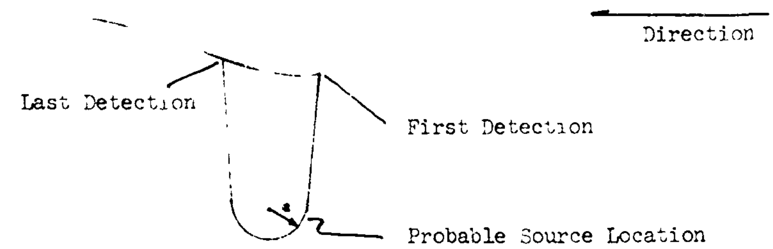
IV. OPERATOR/PLOTTER INTERFACE

The following features represent the operator/plotter interface and are pre-requisites to optimum performance under the anticipated wide range of operating conditions:

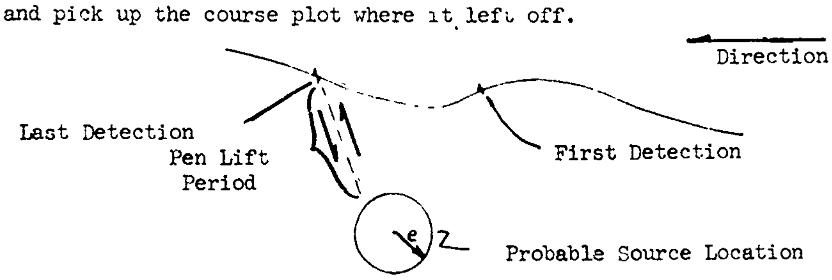
A. SOURCE LOCATION PLOT TECHNIQUE - The single most important aspect of map information interpretation concerns the technique employed for designating a signal source. Two basic guidelines must be observed:

1. No superfluous line work should appear on the map, i.e. if a line has no meaning it has no place.
2. Plot line should, as closely as possible, indicate the area of probable source location.

The most desirable non-interrupted plot is a method that outlines the signal path and encircles the probable source location in the manner illustrated below. The radius(e) of this plot is equivalent to the total plotter/sensor/scalar accuracy and shows the location from which the signal is estimated to emanate.



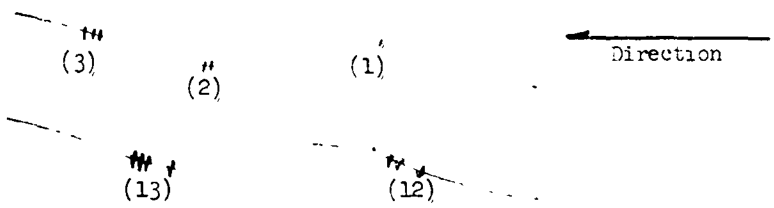
The most desirable interrupted signal indicates the probable source location and the points on the course plot where the signal was first and last detected. As in the previous case, the radius(e) of the plot is a function of the total plotter/sensor/scalar accuracy. Any interrupted plot requires a pen lift capability of the plotter, that is - the pen will lift off the course plot, trace the estimated source location, lift, and pick up the course plot where it left off.



B. <u>SIGNAL STRENGTH INDICATION</u> - To properly evaluate a signal source location plot it is necessary to know the strength of the signal that the plot represents. It is recommended that a signal strength indication in the form of a printed symb[illegible] employed in the source location plot technique. Three symbols representing a faint, moderate and strong signal should be provided. It may be of value to provide a signal strength meter for the operator as the plotter print-out of the signal will be an after-the-fact sequence.

C. SIGNAL ALARM - To alert the operator that the sensor has detected a signal a yellow alert lamp will light and remain lit during the detection period.

D. RANDOM MARK CAPABILITY - During an operation it may be necessary to indicate a particular point with reference to the course plot. For this purpose, it is recommended that the plotter be capable of making, upon operator command (depress button), a discrete mark, such as a cross hatch or sharp jog on the course plot line. By using numerical combinations of marks as a reference to associated notes recorded by the operator in a log book there is no need to disturb the integrity of the plotter to write upon the map.



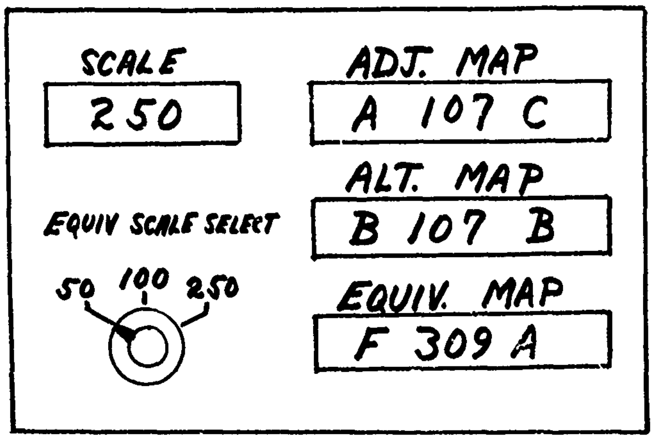
E. ADJACENT MAP INDICATOR - To relieve the operator of the need to predetermine by examination the sequence of maps to be used during a mission, it is necessary to provide an alpha-numeric readout device that will automatically indicate the index number of the map adjacent to the area being plotted. During the period that a map is in the plotter, the readout will indicate the map adjacent to the quadrant being plotted at that time. The adjacent map indicator shall always be in scalar agreement with the map being plotted.

F. ADJACENT SCALE INDICATOR - A numeric readout device shall indicate the scale of the map in the plotter. The scale indicator shall be controlled by map code and require no manual updating.

G. ALTERNATE MAP INDICATOR - To allow operator selection of an alternate map an alpha-numeric readout device will automatically indicate the index number of the alternate map which corresponds to the quadrant being plotted.

H. EQUIVALENT MAP SCALE SELECT SWITCH - To allow the operator to pre-select a different scale map of the area being plotted a scale select switch must be provided. Once selected, the index number of the equivalent map for the scale selected will appear on the Equivalent Map Indicator.

I. EQUIVALENT MAP INDICATOR (SCALAR) - To allow instant selection of a map of either higher or lower scale than that which is in the plotter the index number of the map which represents the selected scalar presentation of the area immediately under the pen shall be displayed on an alpha-numeric readout.



J. CHANGE MAP INDICATOR - A red "change map" signal shall be provided to alert the operator that a map change is imminent. It is recommended that the 'change map' signal light when the trace time from pen to edge of map (straight line) is 15 seconds.

K. PEN - A felt tip pen utilizing a saturated felt reservoir will best withstand vibration and is recommended over a metallic tip, vial reservoir type pen. Pen installation and change must be rapid and require no tools. A minimum of three color availability (red, blue, and black) is recommended. Colors must be discrete and offer clear contrast to the map. A 100 inch ink supply is sufficient to trace a 1/2 hour flight using a 1:50,000 map or a 2 1/2 hour flight using a 1:250,000 map and is recommended as a minimum.

L. CONTROL KNOBS - Control knobs shall, whenever possible, utilize shape and size coding to facilitate tactual operation. The location of controls with relation to each other shall, whenever possible, reflect tactual operation requirements.

M. ILLUMINATION - Red and white panel lamps with brightness controls shall be provided for night illumination of the map surface. Controllable red and white panel illumination will reduce map color washout while allowing sensory adaptation to night vision.

N. SLEW CONTROL - The slew control technique shall consist of two knobs (y axis and x axis) located on an upper portion of the panel face or off the panel face to minimize the possibility of accidental misalignment.

V. A DIFFERENT APPROACH

There is no doubt in the writers mind, that at best, the use of a map plotter is a complex operation requiring highly sophisticated equipment, a large selection of various scale maps, and a well practiced operator. It appears probable that the aircraft used will be a Grumman AO-1AF Mohawk. The Mohawk is the Army's high performance observation plane and its use may be dictated more by payload requirements than by any other factor. It is difficult, however, to picture a twin engine turboprop with a speed capability of over 300 mph as being very agile while flying two hundred feet over a jungle. The Cessna L-19 Bird Dog (115 mph max) might well represent the speed and maneuverability characteristics most desired for low speed, low level search and locate tactics. As an approach to qualifying the detection system for use in a vehicle (such as the L-19) which might better serve the needs of the system, the following proposal is submitted.

A. RECORDED DATA TECHNIQUE-PHILOSOPHY - The plotted data technique involves basically, locating a signal and feeding the signal information together with navigational information into a plotting device which plots the data on a map. Looking at this broad picture in greater detail, the map/plotter interface, the operator/plotter interface, the problems of map overlap, map scale and a myriad of other interrelated considerations come into focus, all of which are a part, not of translating the detected signal into map coordinates, but rather of doing it immediately in the aircraft. There is no question that the information collected by the sensor and the navigational system can only be gained through the use of an aircraft, but it does not necessarily hold that the information so gained must be plotted in the aircraft.

If the sensor and navigational inputs are recorded on a magnetic tape they can be translated onto one optimum size and scale map immediately upon completion of the flight. The adaption of such a technique would eliminate the plotter, preclude the need for an operator and allow sensor detected information to be transcribed directly from the tape to a master map. It must be kept in mind that, in all probability, the information gained through the plotted data technique would be taken from the various scaled map segments and correlated on a single master map.

B. PILOT/EQUIPMENT INTERFACE - The interface between the pilot and the equipment will be as follows:

1. Sensor Controlled Indicator - For the purpose of establishing a directional relationship between the estimated signal source and the aircraft position, a sensor controlled indicator is necessary. The indicator will, upon signal detection, show the direction of the estimated source location and will continue to operate until manually "cleared" by the pilot. The indicator will automatically correct as signal strength increases but will not reflect signal strength decrease. The sensor controlled indicator will allow the aircraft to fly directly into the signal path and pinpoint source location.

2. Signal Strength Meter - A signal strength meter will be provided to indicate relative magnitude of signal being received by sensor. The meter will be provided with a manually reset maximum indication pointer.

3. Signal Alarm (See Section IV, paragraph C).

4. Random Mark Capability - (See section IV, paragraph D). For the purpose of referencing recorded signal information with associated notes in the flight log a device for recording numerical symbols upon the tape is required.

C. COMPUTER/MAGNETIC TAPE INTERFACE - It is necessary to record three items of information regarding a signal detection:

1. Aircraft location (x and y coordinates).
2. Estimated source location (x and y coordinates).
3. Signal strength.

When a detection is made information will be recorded at timed intervals (for example every 3 seconds) during the entire detection period.

D. MAGNETIC TAPE/MAP INTERFACE - Upon completion of a flight the magnetic tape will be fed through a print-out device to provide easily analyzed information from which desired detection may be plotted.

Figure 1

Total Plotter/Sensor Error For Different Map Scales

	1:50,000	1:100,000	1:250,000
1/8" Plotter Error	153 m	305 m	763 m
Sensor Error	700	700	700
Total Error (e)	853 m	1 005 m	1463 m
% (e) Attributable To Plotter	18%	30%	52%
1/16" Plotter Error	76 m	153 m	380 m
Sensor Error	700	700	700
Total Error (e)	776 m	853 m	1080 m
% (e) Attributable To Plotter	10%	18%	35%
1/32" Plotter Error	38 m	76 m	190 m
Sensor Error	700	700	700
Total Error (e)	738 m	776 m	890 m
% (e) Attributed To Plotter	5%	10%	21%

Map Scale

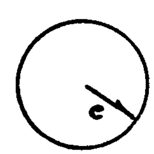


Figure 5-1. Total Plotter/Sensor Error for Different Map Scales.

GENERAL ELECTRIC COMPANY
100 PLASTICS AVENUE

ORDNANCE DEPARTMENT
PITTSFIELD, MASS.

PROJECT 224 MEMORANDUM

SUBJECT: Transient Response Characteristics f the 224 Converter and Detector

DATE: 20 June 1967

DISTRIBUTION:

J.M. Anderson
D.P. Bilyeu
E.J. Blott
J.K. Chapman
P.E. Coffey
S.B. Dunham
S.J. Fusco (2)
R.J. Gillmeister
J.B. Haberl
R. W. Kenyon
H.L. Kramer
M.H. Kurth
R.F. Powers
G.F. Prehmus
G. Skala
F.W. VanLuik

I. Summary

The data presented in this memorandum show that the transient response characteristics of the converter and detector designed for project 224 are important in determining the sensitivity of the instrument for an airborne application in which the aircraft travels relatively rapidly through the air mass. The effects are illustrated by the curves of Figures5-..

A step input of nuclei or convertable effluent concentration that is 5 to 1 above the background is shown as Figures2 (a). The resulting transient response of the output of the converter and detector is shown as Figures2 (b). The response is characterized by two phases. The first is a pure transport delay which represents the time required for the first sample to pass through tubing and chambers. For the project 224 application this delay can be measured and a compensation can be made for it.

I. (con.)

The second phase is the transient rise of the output signal in response to the input. This response is due primarily to the mixing of air samples in the ionization, acid, and humidification chambers of the converter and detector. In general it is not possible to compensate for this transient since the output signal strength above background is a function of signal strength and length.

The typical situation for the 224 system is one in which the aircraft flies through an effluent plume of fairly short duration as shown as figure 5-2 (c). The output of the detector for this input is plotted as Figure 5-2 (d). Note that in this case the output signal is greatly distorted with respect to the input and the maximum amplitude is much less. The transient response characteristics of the converter and detector have therefore reduced the sensitivity of the instrument to signals of this class and have blurred the length and the time at which they occur. Both effects are significant in the 224 application.

The curves of Figure 5-2 have been drawn without showing the effects of sampling rate which is either 5 or 10 cps for the 224 detector. This was done because the analysis of the probable transient response of the detection system has shown that a 5 cps sampling rate is adequate for following the response. The chief benefit of the capability to shift to a 10 cps sampling rate is that this will reduce the system time constants by 1/2 from the 5 cps case.

In summary transient response characteristics are an important trade off factor that must be considered in the overall design of the combined 224 converter and detector system.

II. Analysis

Air flows through a series of interconnected reaction chambers in the combined converter and detector as shown in block diagram form as Figure 2. The air flow through the detector is at a rate of F cc/sec. When complete mixing occurs in a chamber of volume Q, a time constant, T, is defined for that chamber as $T = Q/F$. This time constant determines the transient response of the output of the chamber to a change in air mixture concentration at the inlet. By combining the transient response characteristics of the three chambers, the overall transient response of the converter and detector can be determined.

Assumptions

The following assumptions were made to develop an approximate function for this equipment.

1. Flow is continuous
2. Complete mixing occurs in each chamber
3. No mixing occurs in the interconnection tubing
4. The volumes of the ionization and HCL chambers are determined by either of two hypotheses.

Case 1

The number of condensation nuclei generated by a converter is proportional to the average time that a sample spends in the ionization chamber and the average time that the sample spends in the HCL chamber.

Concentration of CN = K T_1T_2 - where K is a constant

For this case the best possible transient response and greatest sensitivity results when the time constants are equal.

Case 2

The number of condensation nuclei generated by a converter is primarily determined by the average time that a sample spends in the HCL chamber.

Concentration of CN = K T_2

The ionization process is required but the chamber can be much smaller than the HCL chamber.

Transfer Functions

In the development of the transfer functions the term involving pure transport delay has been omitted. This was done because it does not affect the transient response of the equipment except for a translation of the time axis. In the use of data from the detector compensation can be made for this time translation based on the measured delay for each installation. Compensation cannot be made for the transient effects which are analyzed in this paragraph.

Detector

In the CN mode the detector operates without a converter. Therefore the response of the detector alone is of interest. In this case only the humidifier is involved. The transfer function for the concentration of condensation nuclei at the output of the humidifier C_3 to the concentration at the inlet is:

$$\frac{C_3}{C_2}(s) = \frac{1}{1+ST_3}$$

The corresponding time function for a unit step input in C_2 is:

$$C_3(t) = 1-e^{-t/T_3}$$

Converter and Detector - Case 1

The transfer function for the combined converter and detector for case 1 is

$$\frac{C_3}{C_0}(s) = \frac{K\, T_1 T_2}{(1+ST_1)(1+ST_2)(1+ST_3)}$$

For equal chamber volumes in the converter $T_1 = T_2$ and the transfer function becomes

$$\frac{C_3}{C_0}(s) = \frac{K\, T_1^{\,2}}{(1+ST_1)^2\,(1+ST_3)}$$

Converter and Detector - Case 1 (Cont.)

The time response for a unit step at the inlet is

$$C_3(t) = K \left[T_1^2 - \left(\frac{T_1 T_3}{T_1 - T_3} \right)^2 e^{-t/T_3} - \left\{ t + \frac{T_1(T_1 - 2T_3)}{T_1 - T_3} \right\} \left(\frac{T_1}{T_1 - T_3} \right) e^{-t/T_1} \right]$$

Converter and Detector - Case 2

The transfer function for the combined converter and detector for case 2 is

$$\frac{C_3}{C_0}(s) = \frac{K\, T_2}{(1+ST_1)(1+ST_2)(1+ST_3)}$$

The time response for a unit step at the inlet is

$$C_3(t) = K \left[T_2 - \frac{T_1^2 T_2}{(T_1 - T_2)(T_1 - T_3)} e^{-t/T_1} - \frac{T_2^3}{(T_2 - T_1)(T_2 - T_3)} e^{-t/T_2} - \frac{T_3^2 T_2}{(T_3 - T_1)(T_3 - T_2)} e^{-t/T_3} \right]$$

III. Results

Detector

The transient response of the present project 224 detector was recorded at the Electronics Laboratory. The response can be approximated by a simple exponential time constant of 0.6 seconds at the 5 cps pumping rate. The resulting response to a step input is

$$C_3(t) = 1 - e^{-t/0.6}$$

This function is plotted on Figure 5-4. Also plotted on Figure 5-4 are durves showing the detector output for unit input pulses of varying widths in time. These are important for the situation in which the detector is carried on a moving vehicle since they determine the minimum effluent plume widths in distance that can be detected. This relationship is further illustrated by the curves of Figure 5-5 that show the minimum input pulse time widths required for the detector output to exceed detection threshold levels of 50%, 150%, and 250% above background as a function of input signal to background ratio. The pulse width time axis can be converted to a plume width distance axis at various vehicle velocities by the curves of Figure 5-6.

The 224 detector is designed so that the pumping rate can be increased to 10 cps by changing the motor and pump. If the humidifier volume is unchanged the effective time constant of the detector is cut in half. This will result in a step response to a unit step input of

$$C_3(t) = 1 - e^{-t/0.3}$$

The curves of Figures 5-4 and 5-5 apply to this response if the time axis is doubled. A note has been put on these curves to indicate this fact.

Detector and Converter - Case 1

A current estimate for a converter design of this type is that the ionization and HCL chambers should each provide an average dwell time of one second. For this case the time response equation for a unit step input becomes

$$\frac{C_3(t)}{K} = 1 - 2.25\, e^{-t/.6} - (t-.5)\, 2.8\, e^{-t}$$

III. Results (cont.)

Detector and Converter - Case 1 (cont.)

This time response is plotted on Figure 5-7 along with associated curves showing the combined converter and detector response to unit input pulses of varying time widths. The later curves were used to generate the curves of Figure 5-8 that show the minimum input pulse time widths required for the combined output to exceed detection threshold levels of 50%, 150%, and 250% above background as a function of input signal to background ratio. Again Figure 5-6 applies for converting the time axis to a distance axis.

It is of interest to examine the time response of the system if the time constants are cut in half. This would happen if the flow rate through the combined converter and detector is doubled. Under the assumption that nuclei output is proportional to the average time in each converter chamber, the converted nuclei signal output under steady state conditions is cut by a factor of 4 for this case. By the same reasoning the converted background signal is also cut by a factor of 4 but the normal condensation nuclei background of the atmosphere is not changed. The time response for a unit step input for this situation is

$$\frac{C_3(t)}{K} = \frac{1}{4}\left[\frac{1}{4} - 2.25\, e^{-t/.3} - (2t-.5)2.5\, e^{-2t}\right]$$

The time response plus the response of the combined converter and detector to unit pulses of varying width are plotted as Figure 5-9. The associated detector threshold level curves are plotted on Figure 5-10 under the assumption that the converted background has been reduced by a factor of 4. For the situation of comparison with atmospheric condensation nuclei background the curves apply but the signal to background ratio used to enter the curves would be 1/4 that used for Figure 5-8.

Detector and Converter - Case 2

For this case it is estimated that the chamber for the HCL reaction should again provide a one second average dwell time but that the ionization chamber can be five times smaller. For these values of T_1 = 0.2 seconds, T_2 =1.0 seconds, and T_3 = 0.6 seconds the time response equation for a unit step input is

$$\frac{C_3(t)}{K} = 1 - .125\, e^{-5t} - 3.125\, e^{-t} + 2.25\, e^{-t/.6}$$

III. Results (cont.)

Detector and Converter - Case 2 (cont.)

The time response for this case is plotted as Figure 5-11 along with the responses for unit pulse inputs of various widths.
q The detector threshold level curves that were derived from Figure 5-11 are plotted as Figure 5-12.

The effect of decreasing the time constants was investigated for the situation in which each was cut in half. For this case the assumption that the converted nuclei output is proportional to the average time spent in the HCL chamber results in a reduction in converted nuclei signal output of one half. The converted background signal is also cut by a factor of two but the atmospheric condensation nuclei background is unchanged. The time response for T_1 = 0.1 seconds, T_2 = 0.5 seconds, and T_3 = 0.3 seconds is

$$\frac{C_3(t)}{K} = \frac{1}{2}\left[\frac{1}{2} - .125\, e^{-10t} - 3.125\, e^{-2t} + 2.25\, e^{-t/.3}\right]$$

This equation is the same as that previously derived for this case with the larger time constants except for an amplitude decrease by 1/2 and a doubling of the exponential time factors. Therefore the data plotted on Figure 5-11 applies with the amplitude scale doubled (i.e., 1.0 becomes 0.5) and the time scale halved (i.e., 5 seconds becomes 2.5 seconds). The detector threshold curves of Figure 5-12 also apply with only the time scale halved for converted signals. For comparison with atmospheric condensation nuclei background the signal to background scale applies but the signal would be 1/2 of that used with the longer time constant case.

IV. Conclusions

The results of this investigation indicate that the transient response characteristics of the combined converter and detector is an important factor that must be traded off against steady state sensitivity in order to achieve an optimum detector system for project 224. In particular the ability to detect relatively strong signals of short duration may not be achieved unless this is considered during the design. In addition the effluent plum e width can be seriously distorted so that the prediction of source location is not possible.

IV. Conclusions (cont.)

These effects are best illustrated by the consideration of a typical case.

Conditions:

Signal to Background Ratio	5/1
Signal Pulse Width	1 second
Aircraft Velocity	100 knots

(Aircraft Flies Perpendicular to Plume)

For a converter and detector of Case 1 design with one second time constants, Figure 5-8 shows that at a threshold detection level 150% above background a detection is barely made. However Figure 5-7 shows that if a 50% level is used the detection level is exceeded from 0.95 seconds to 4.75 seconds for a period of 3.8 seconds. This would result in a measured plume width of 196 meters rather than the actual 51 meters. The conclusion is that this is not a good detection system for this type of signal.

For the case 1 converter and detector with the time constants reduced by 1/2, Figure 5-10 indicates that the 250% threshold level would be triggered by the 5/1 pulse of one second duration. An examination of Figure 5-9 shows that the 150% threshold level would be exceeded from 0.97 seconds to 2.05 seconds for a pulse width of 1.08 seconds while the 50% level would be exceeded from 0.46 seconds to 3.20 seconds for a 2.74 second pulse width. The corresponding distances are 56 meters and 141 meters. The improvement with the decreased time constants is evident.

The converter and detector case 2 situation for the same input is described by Figures 5-11 and 5-12. For the one second HCL chamber time constant the 150% threshold limit is exceeded from 1.4 to 1.83 seconds for a 0.43 second width while the 50% limit is exceeded from 0.58 seconds to 3.32 seconds for a 2.74 second pulse width. These result in measured trail widths of 22 meters and 141 meters respectively.

Now for the case 2 situation with the time constants reduced by 1/2 the 250% threshold limit is exceeded. The 250% level is exceeded between 0.76 seconds and 1.62 seconds for a 0.86 second width. The 150% threshold level is exceeded between 0.52 seconds and 1.96 seconds for a 1.44 second period while the 50% level is exceeded between 0.29 seconds and 2.55 seconds for a 2.26 second pulse width. Corresponding trail widths are 44, 74, and 116 meters respectively. Again the improvement with decreased time constants can be seen.

IV. Conclusions (cont.)

The data examined for this condition indicates that where possible the time constants must be reduced to achieve adequate response and that the threshold level used to determine pulse width should be increased with increased detector output signal amplitude.

The question of detector sampling rate requirements can be examined with respect to the detector only transient response of Figure 3. Since the 5 cps sampling rate results is three samples in a period of one time constant, sampling rate will not limit the response of the detector. Similarly it will not limit the effectiveness of the detector in sampling plumes of a flow width. A decrease in sampling rate would bring it to a condition of effecting detector response.

When the detector sampling rate is increased to 10 cps the flow rate through the detector is doubled thereby cutting all chamber time constants by 1/2. Therefore the same relationship of sampling rate to time constants will be maintained.

A M VanBlarcom

A. M. VanBlarcom - Consulting Systems Engineer
Electro-Mechanical Equipment Operation
Mail 8058 - Ext. 5204

/s

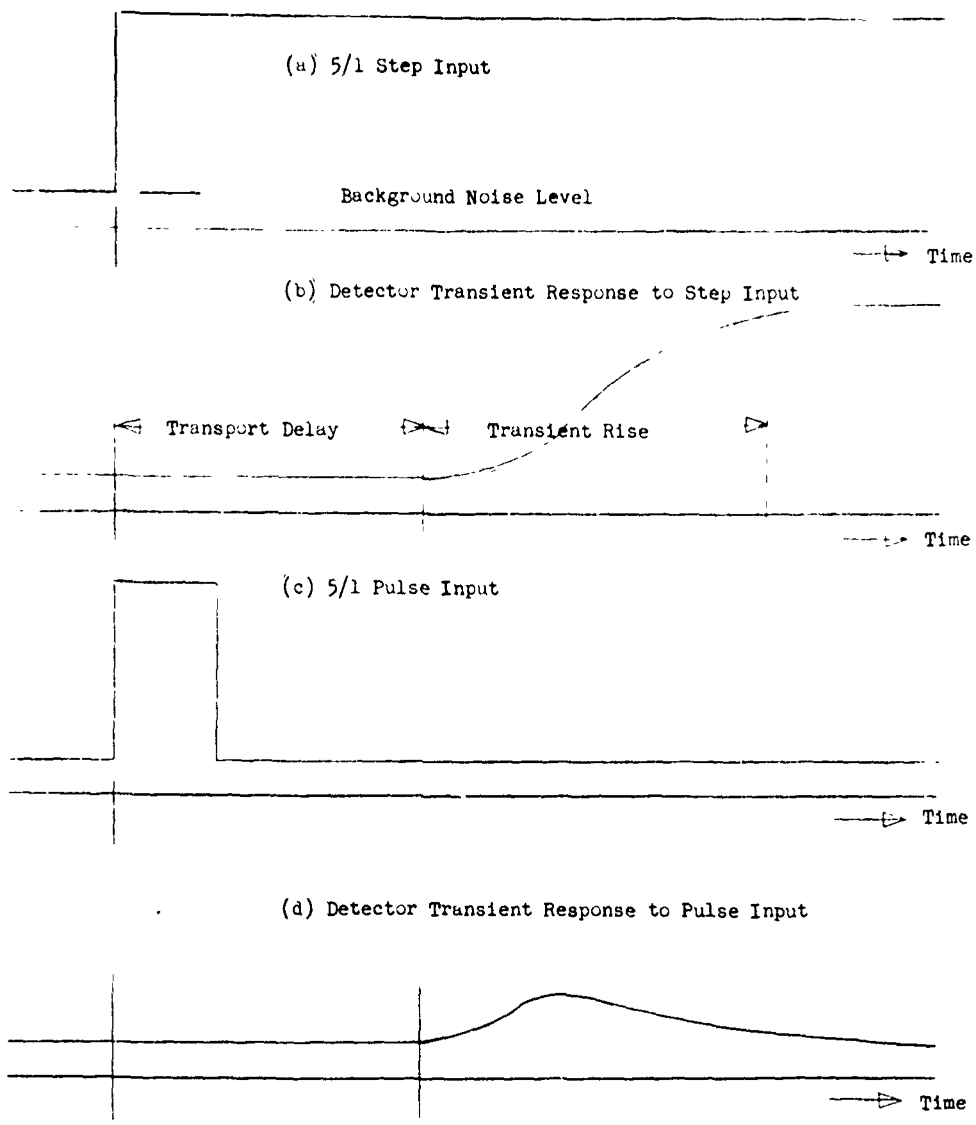
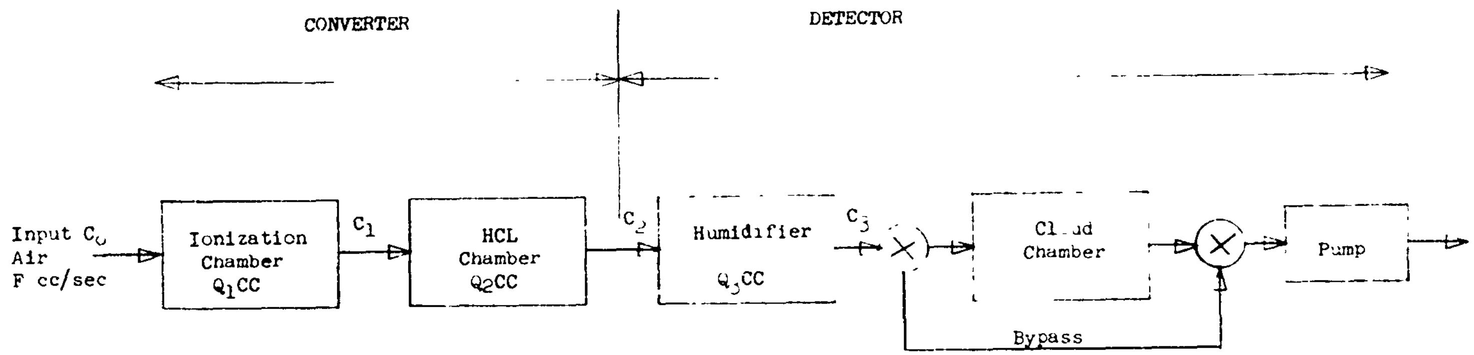


Figure 5-2. Typical Converter and Detector Response Characteristics.



CONVERTER AND DETECTOR BLOCK DIAGRAM

F = flow rate cc/sec

Q = chamber volume cc

C = nuclei concentration

Figure 5-3. Converter and Detector Block Diagram.

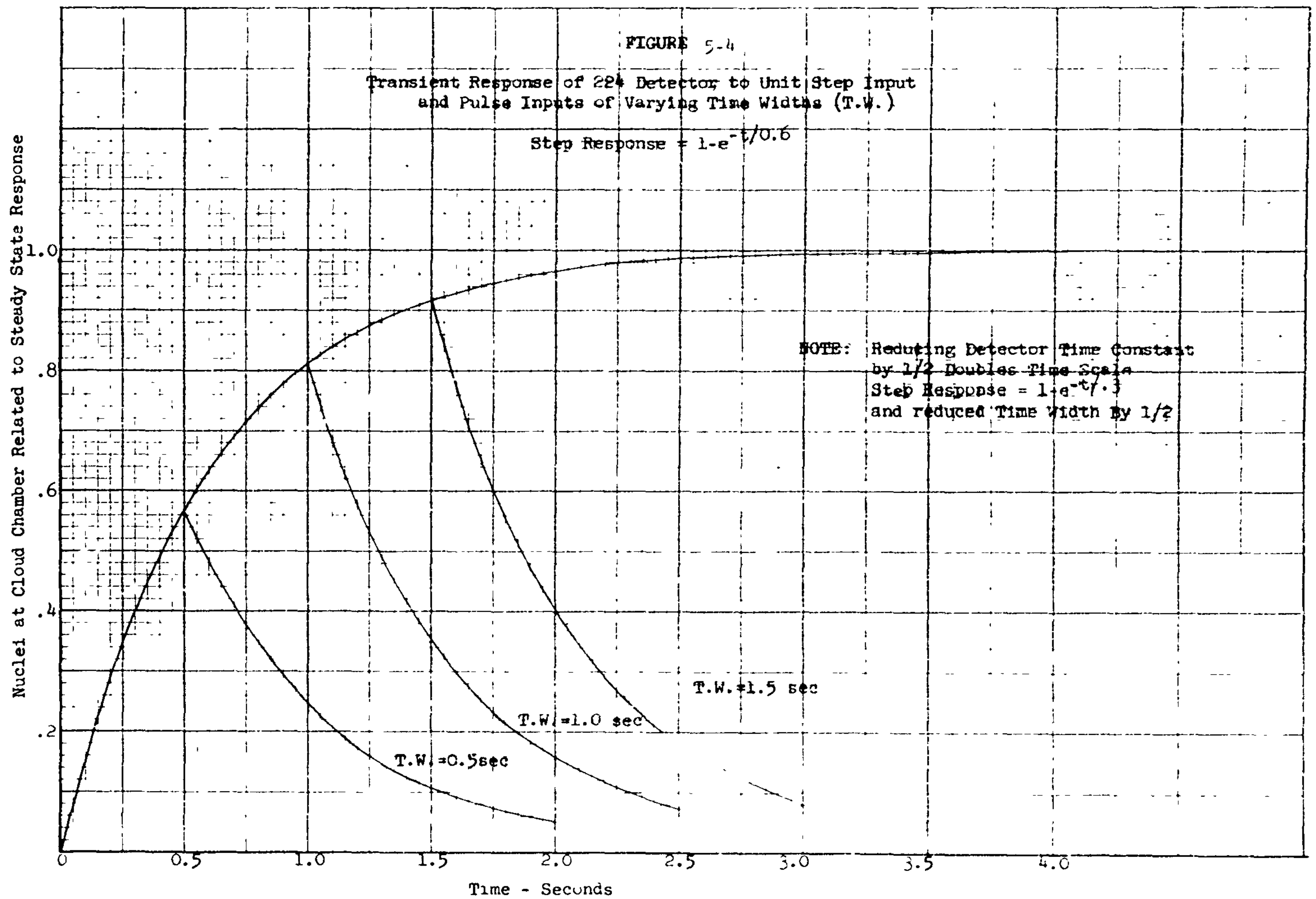


Figure 5-4. Transient Responses.

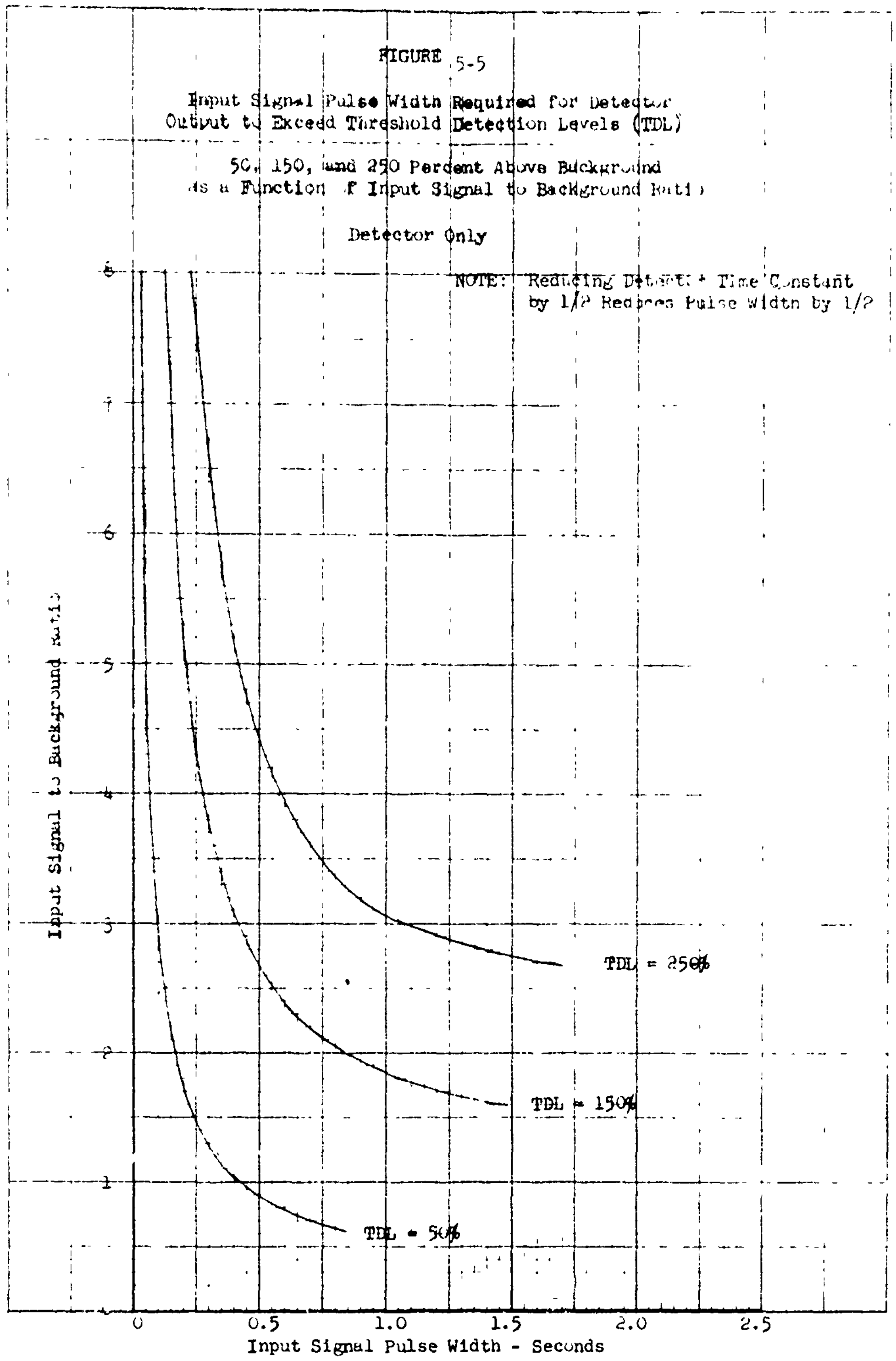


Figure 5-5. Input Signal Pulse Widths for TDL Detector Only

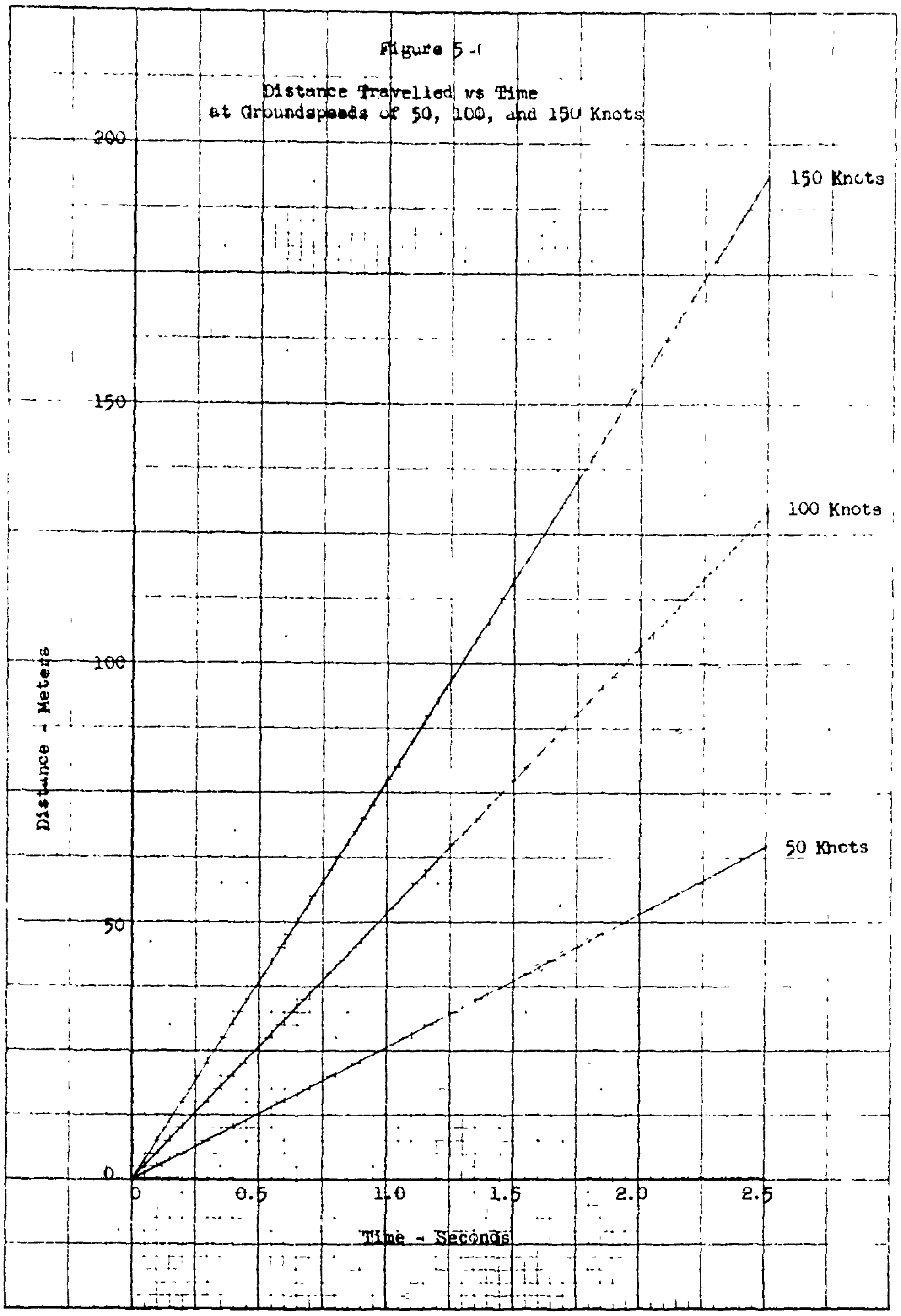


Figure 5-6. Distance Traveled vs Time.

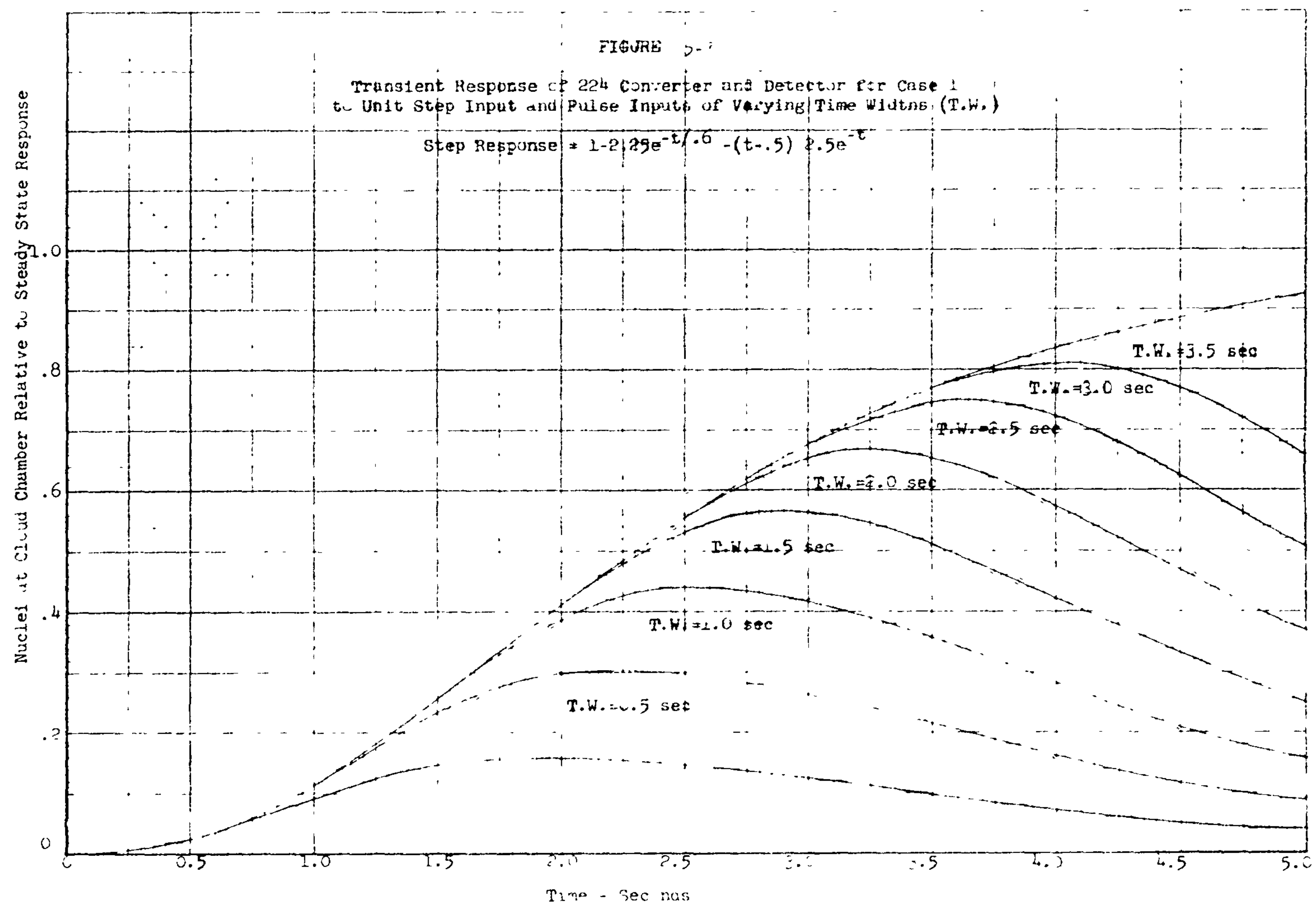


Figure 5-7. Transient Responses for Case 1.

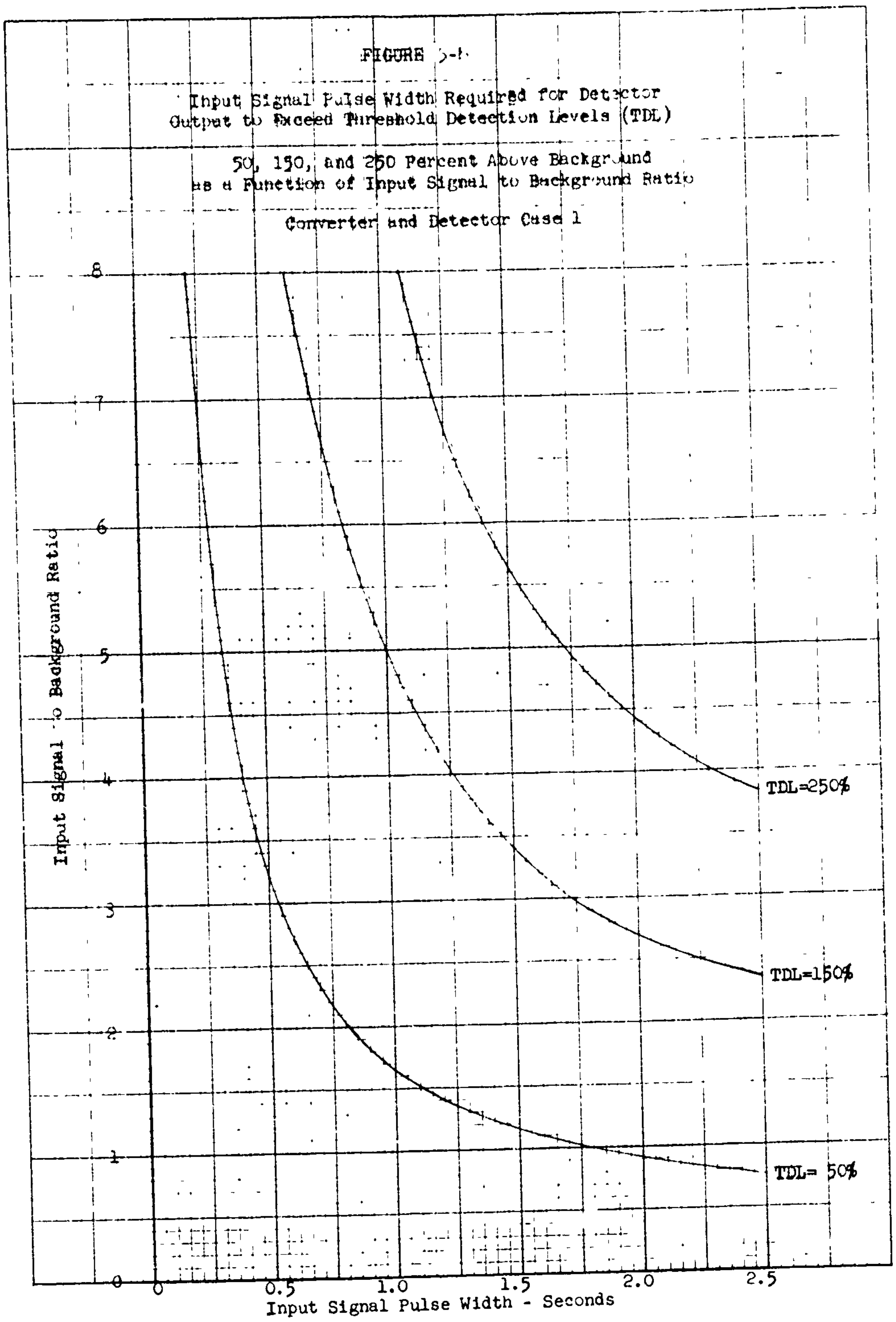


Figure 5-8. Input Signal Pulse Widths for TDL.

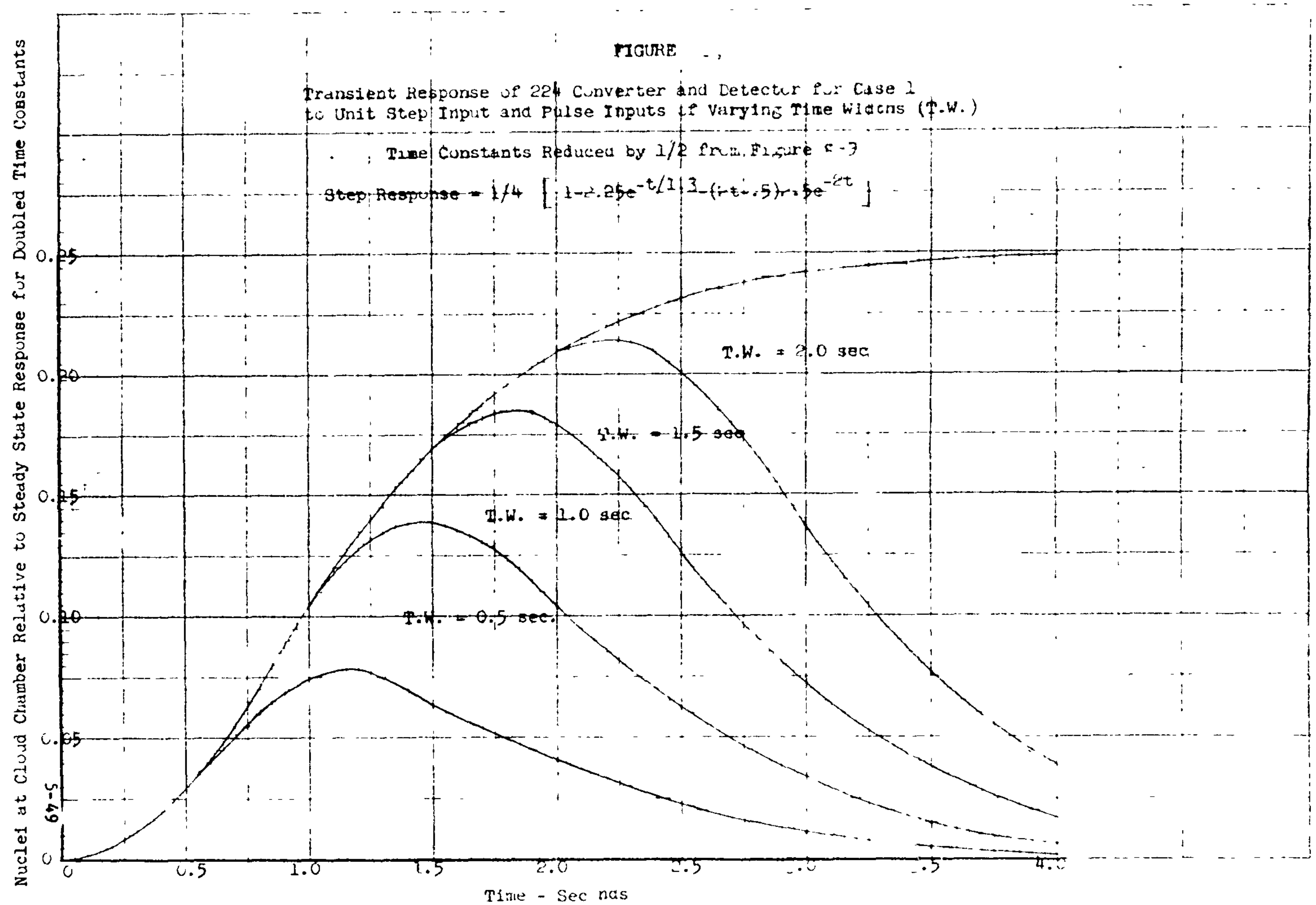


Figure 5-9. Transient Responses Case 1-TC Reduced by One-Half

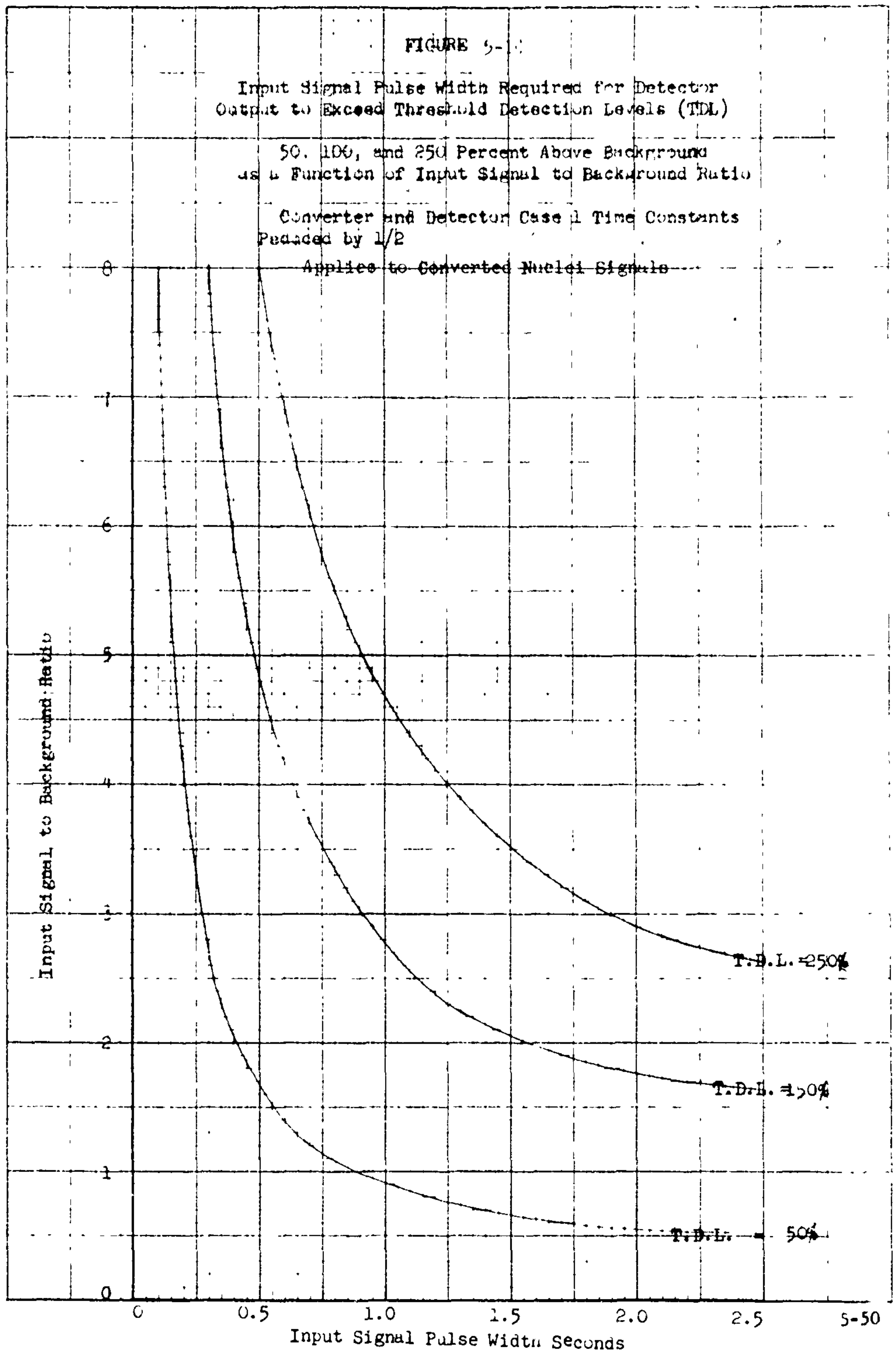


Figure 5-10. Input Signal Pulse Widths for TDL-TL Reduced by One-Half.

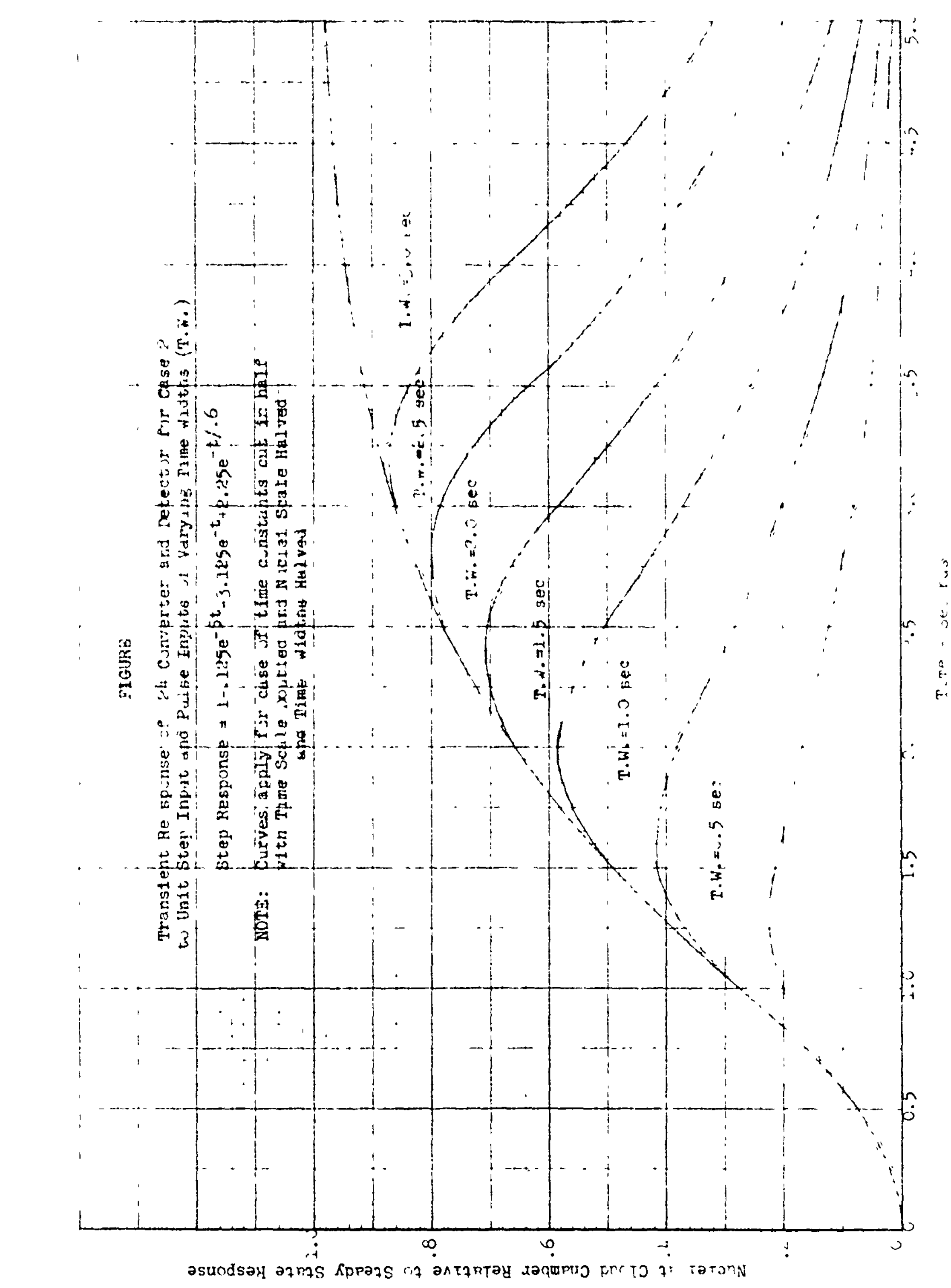


Figure 5-11. Transient Response—C...

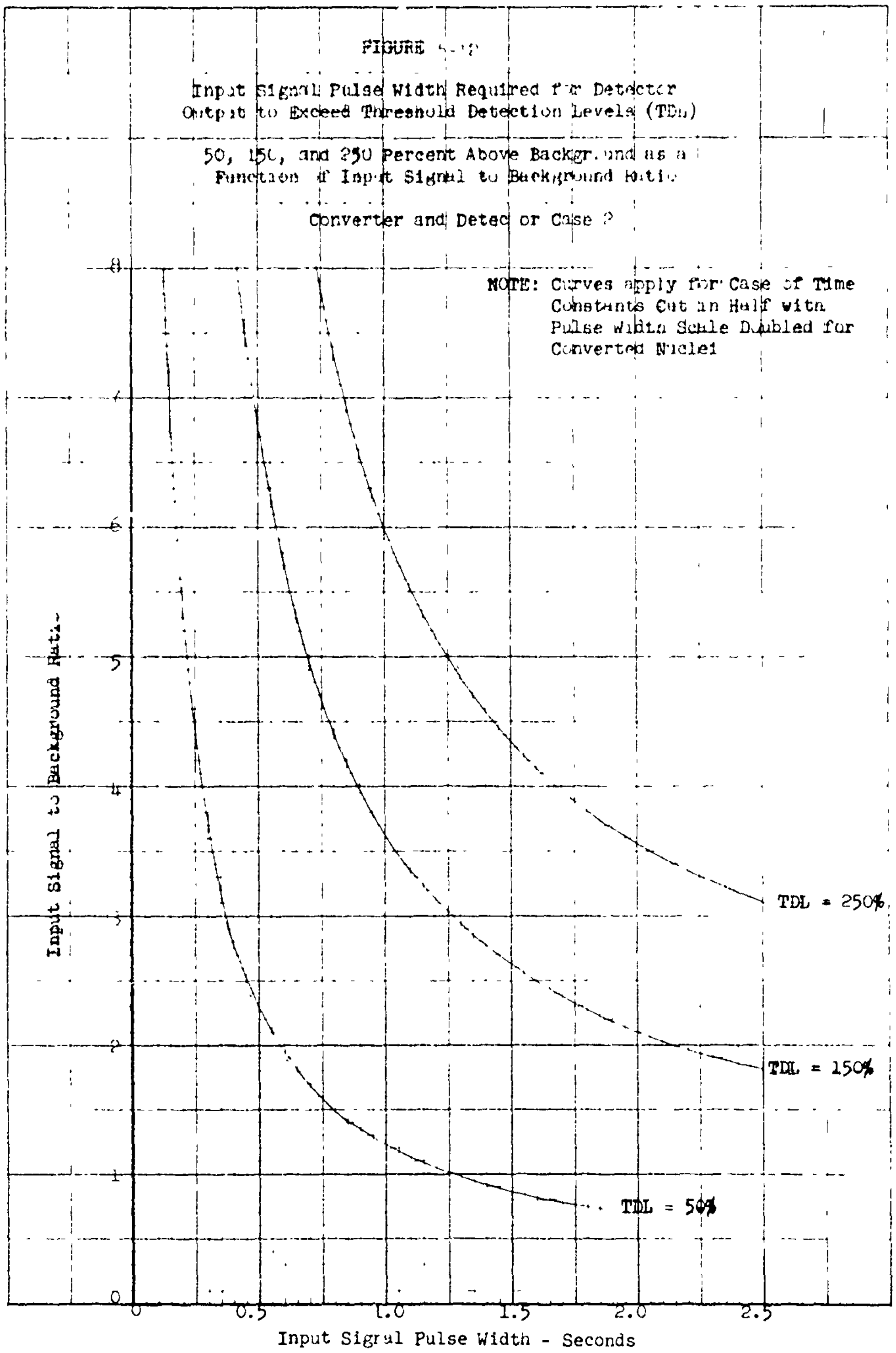


Figure 5-12. Input Signal Pulse Widths for TDL-Case 2.

GENERAL ELECTRIC COMPANY
100 PLASTICS AVENUE

(ING DEPARTMENT
PITTSFIELD, MASS.

PROJECT 224 MEMORANDUM

SUBJECT: Transient Response Data for the
224 Converter and Detector

REFERENCE: PROJECT 224 Memo
Transient Response Characteristics of the
224 Converter and Detector
20 June 1967

DATE: 11 September 1967

DISTRIBUTION:

JM Anderson
DP Bilyeu
JK Chapman
PE Coffey
SB Dunham
J Fusco
RJ Gillmeister
JB Haber
RW Kenyon
HL Kramer
MH Kurth
EB McCrohan
RF Powers (5)
GF Prehmus
AJ Rider
G. Skala
FW VanLuik

I. Objective

In the referenced memorandum the transient response of the converter and detector were shown to be important factors in the ability of an airborne system to detect relatively narrow effluent plumes. Therefore a three phase investigation was started (1) to measure the actual response of a 224 detector and converter to step inputs, (2) to find means of improving the transient response characteristics without impairing steady state sensitivity, and (3) to develop an analytical model of the converter and detector so that performance against various signals can be predicted.

II. Summary of Results

Experiments were run with both a 223 detector and a 224 detector and with various converter designs. A 25 percent reduction of the measured detector time constant was obtained by blocking off unused volumes in the humidifier chamber. A 50 percent reduction in the converter time constant was achieved by changing the geometry of the design plus reducing the volume. The sensitivity of the redesigned converter was measured as being the same as that of the laboratory converter standard. Further improvements may be possible in the future. The resulting step response of a 224 Phase 2 detector is shown on Figure 5-13 while that for this detector plus a conical converter design is shown on Figure 5-16

As part of the experimental program data was measured to show that the response of a converter and detector was the same for gas as it was for CN. Therefore all of the remaining tests were run by measuring the response to CN step inputs.

An analytical model was developed for predicting the transient response of the detector and converter. Excellent correlation was obtained between this model and the measured step response data. This model has been used to calculate the response of the 224 Phase 2 detector and the detector plus converter to pulse inputs of various widths. This response data is presented on Figures 5-20 and 5-21.

The transient response characteristics of the 224 Phase 4 detector will be reported upon when it becomes available.

III. Measured Response Data

Step inputs of condensation nuclei concentration were used to measure the transient response of the 223 and 224 Phase 2 detectors and of these detectors plus various converters. The sampling rate of the detectors introduces a staircase like stepping in the response. A smooth curve was drawn through these responses and used to determine the time required to reach 63 percent of maximum.

The response of the 224 Phase 2 detector with blocks in the humidifier to a step input is shown on Figure 5-13 The effect of blocking off unused humidifier volume is illustrated by Figure 5-14 in which the same detector response is measured but without the blocks. As can be seen the time to reach 63 percent of maximum is reduced from about 0.4 seconds to 0.3 seconds by the blocks.

III. (cont.)

Similar results were obtained in tests of the 2.5 detector. In this case the response time was cut from 0.4 seconds to 0.25 seconds.

Converter geometry and volume were shown to be major factors in the transient response characteristics of the combined converter and detector. Figure 3 shows the response to a step input of a good design. Note that in this case the time for the combination to reach 63 percent of maximum increase is to about 0. seconds. For other designs this time was stretched to as much as 1.6 seconds. This particular converter design consists of a 3/4 inch cylinder 4 inches long with a plug inserted in the outlet end to form a ... Conversion sensitivity was measured as being equal to that for the laboratory standard.

IV. Transient Analysis Program

A digital computer transient analysis program was developed to simulate the detector and converter. Excellent correlation was obtained between the calculated results and measured data.

The block diagram upon which the analytic model is based is shown as Figure 5-16. Two time constants are represented by volumes Q1 and Q2 in the converter and humidifier. The input consists of concentration $C\phi$ at a flow rate F1. The output concentration of the converter is C1. That divides into two paths with F2 flowing through the humidifier and cloud chamber and F1-F2 bypassing the detector. The nuclei concentration output of the humidifier is C2 and is measured by the detector.

The pump has two exhaust strokes for each cycle of detector operation. Therefore it was assumed that on even numbered strokes the flow was through the humidifier while on odd strokes bypass flow occurred.

Difference equations were written to represent simple exponential mixing in the chambers. For example the concentration in the converter was experessed as

$$Cl_i = Cl_{i-1} \left(1 - \frac{\Delta V}{Q1}\right) + C\phi_i \frac{\Delta V}{Q1} 1$$

The fraction $\Delta V/Q1$ is the percentage change of air in the converter for each cycle while i is the cycle number.

The computer program was written in BASIC language for the GE time sharing computer system. The program listing is included as Figure 5-17. At the bottom of the sheet is a typical run. The basic converter and detector parameters are entered in data statement 400. D is the time interval with each 0.1 seconds representing one pump cycle or one half of a detector cycle at a 5 pps rate. Input concentrations CØ are read in sequence from data statements 410 and 420. The printed converter and detector time constants are the ratios of volume to flow rate.

The best correlation of calculated to measured data was obtained with the following set of parameters.

Q1 = 16.25 cc

F1 = 25 cc/sec

Q2 = 6.75 cc

F2 = 15 cc/sec

The response of the detector alone is obtained by setting Q1 to zero. On Figure 5-18 the calculated step response of the 224 Phase 2 detector is compared with two measured responses. The calculated response of this detector with the conical converter is shown on Figure 5-19 along with three measured responses. The calculated data is for an input step occurring at an odd pump cycle. The even cycle data fits smoothly between these points. Correspondance between calculated and measured data is quite good.

The analytical model was used to predict transient performance for pulse inputs of various widths. The detector pulse response is plotted as Figure 5-20 and the converter/detector response is plotted as Figure 5-21.

AM Van Blarcom

A. M. VanBlarcom - Consulting Systems Engineer
Electro-Mechanical Equipment Operation
Mail 8058 - Ext. 5204

/s

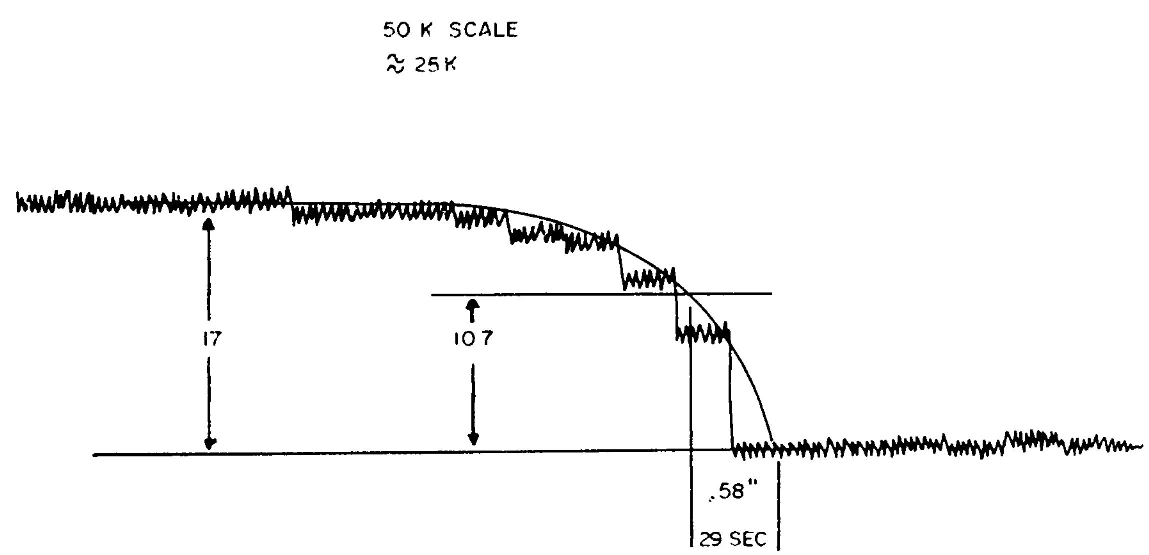


Figure 5-13. Detector with Blocks Step Response to CN

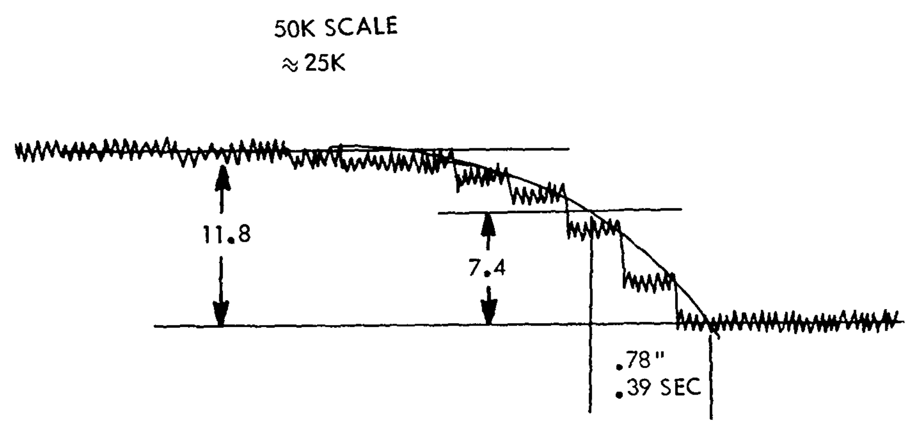


Figure 5-14. Detector Without Blocks Step Response to CN.

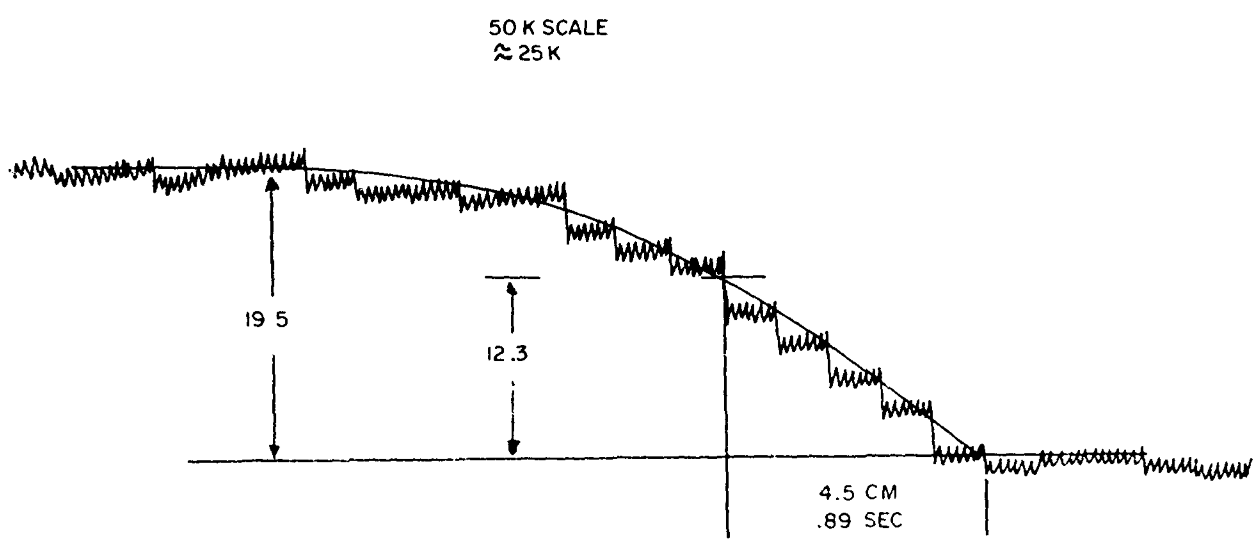
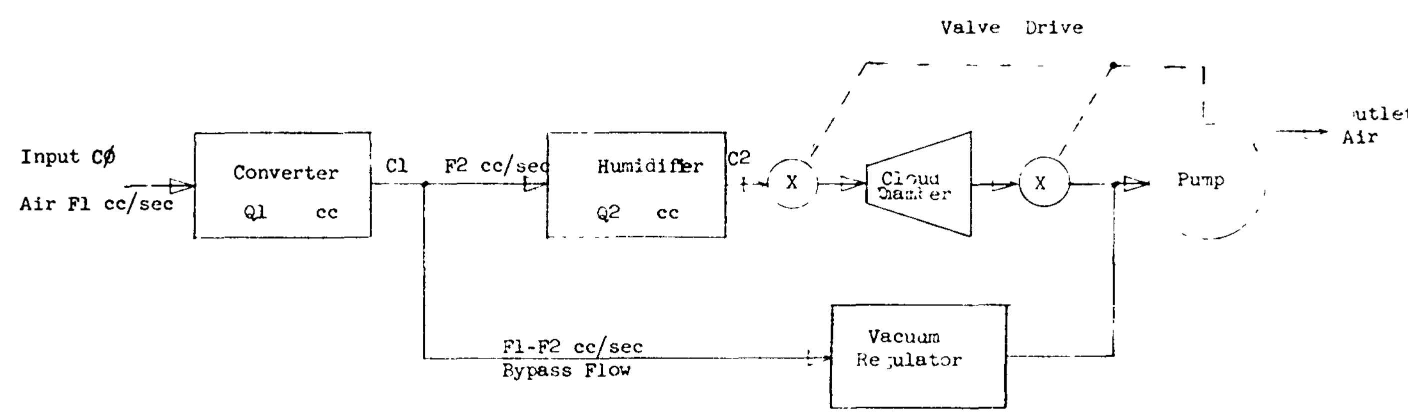


Figure 5-15. Detector—Converter Step Response to CN



CONVERTER AND DETECTOR BLO K DIAGRAM

F = Flow Rate cc/sec
Q = Chamber Volume cc
C = Nuclei concentration per cc

Figure 5-16. Detector—Converter Block Diagram.

IT.

```
XNT RE      9:41     S2 TIE 09/12/67

10 LET T=0
20 LET C0=
30 LET C1=0
40 LET C2=0
50 READ Q1,F1,Q2,F2,D
60 PRINT "Q1="Q1,"F1="F1,"Q2="Q2,"F2="F ,"D="D
70 LET T1=Q1/F1
80 LET T2=Q2/F2
90 PRINT "CONVERTER TIME CONSTANT="T1
100 PRINT "DETECTOR TIME CONSTANT="T2
110 PRINT
120 PRINT "TIME","C0","C1","C2"
130 PRINT
140 PRINT T,C0,INT(C1*1000+.5)/1000,INT(C2*1000+ .5)/10
150 READ C0
160 LET T=T+D
170 IF T1=  T THEN 2
180 LET C1=C1*(1-(F1-F2)*2*D/Q1)+C0*(F1-F2)*2*D/Q1
190 PRINT T,C1,INT(C1*1000+.5)/1000
200 READ C0
210 LET C2=C2*(1-2*D/T2)+C1*2*D/T2
220 LET C1=C1*(1-F2*2* )/Q1)+C0*F2*2*D/Q1
240 LET T=T+D
250 GO TO 140
260 READ C0
270 LET C2=C2*(1-2*D/T2)+C1*2*D/T2
280 LET T=T+D
290 GO TO 140
400 DATA 16.25,25,6.75,15,.1
410 DATA 1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,
420 DATA 0,1,0,0,1, ,1,0,0,0,0,0,1,0,0,0,1,0,0
500 END

RUN

XNT RE      9:43     S2 TIE 09/12/67

Q1= 16.25        F1= 25        Q2= 6.75        F2= 15        D= .1
CONVERTER TIME CONSTANT= .65
DETECTOR TIME CONSTANT= .45
```

TIME	C0	C1	C2
0	0	0	0
.1	0	0	
.2	1	.185	1
.3	1	.285	
.4	1	.417	.127
.5	1	.469	
.6	1	.583	.266
.7	1	.634	
.8	0	.517	.442
.9	0	.454	
1.	0	.37	.447

Figure 5-17. Basic Computer Program Listing.

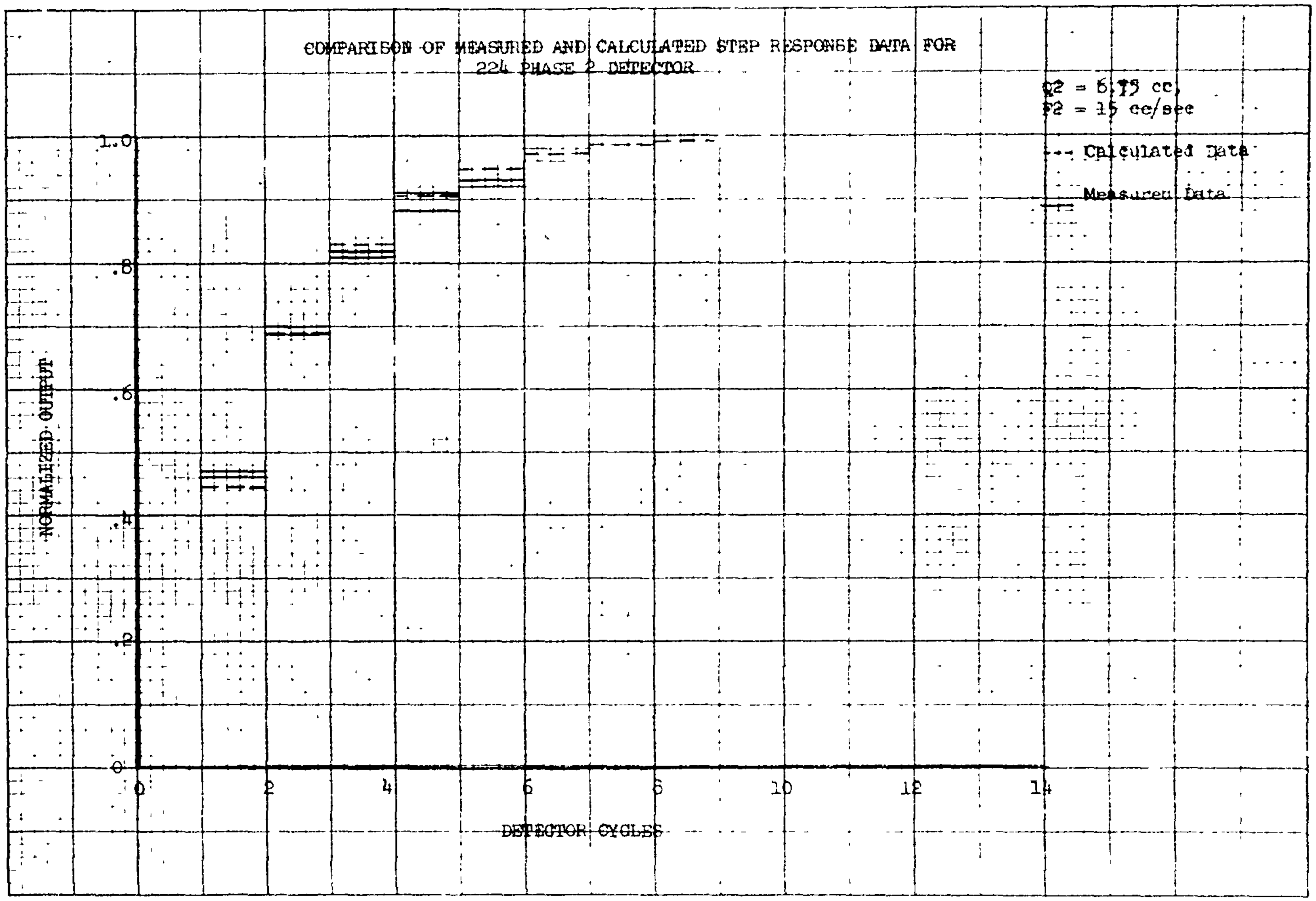


Figure 5-18. Measured and Calculated Step Response—Detectors.

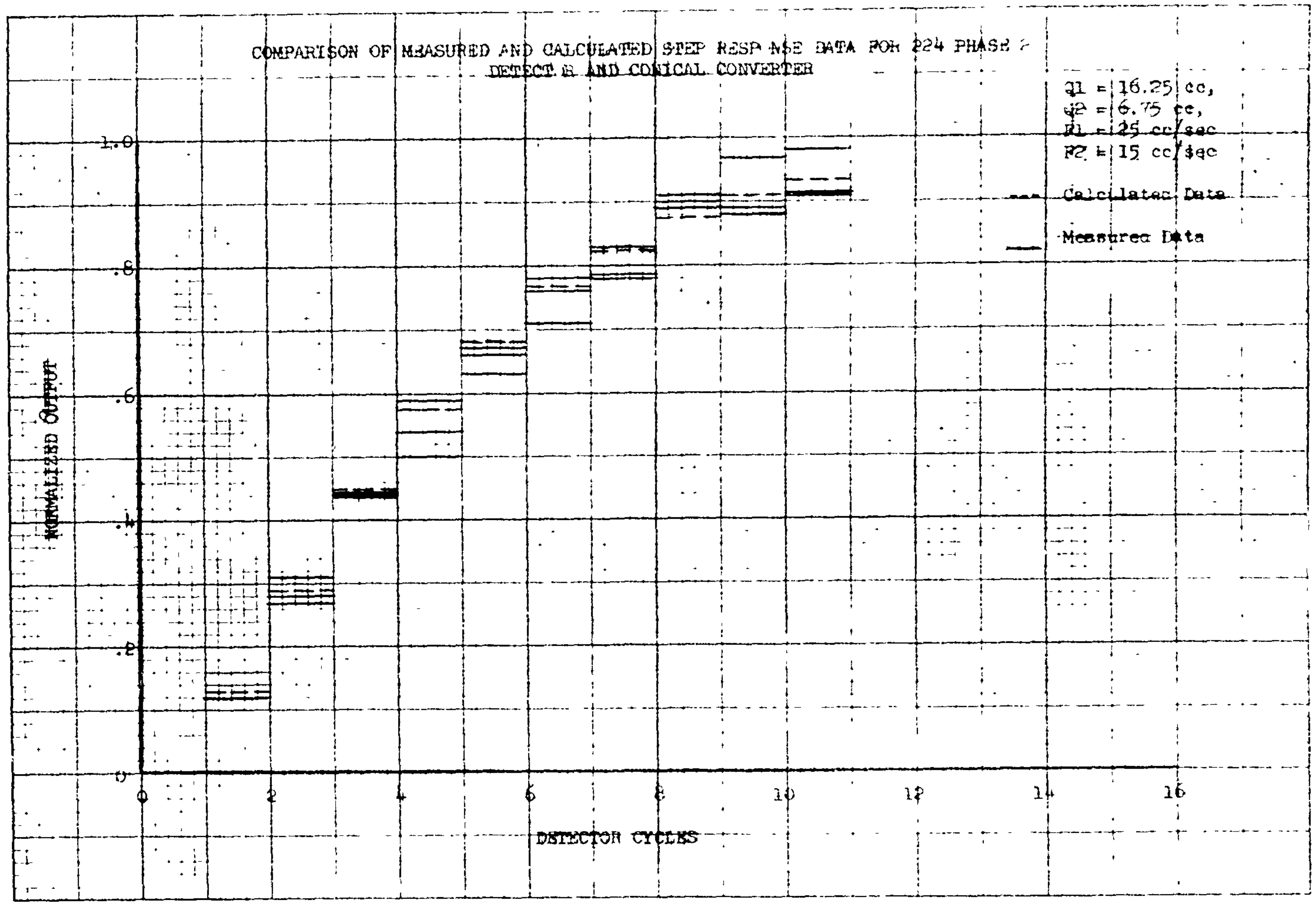


Figure 5-19. Measured and Calculated Step Response--Detectors and Converters.

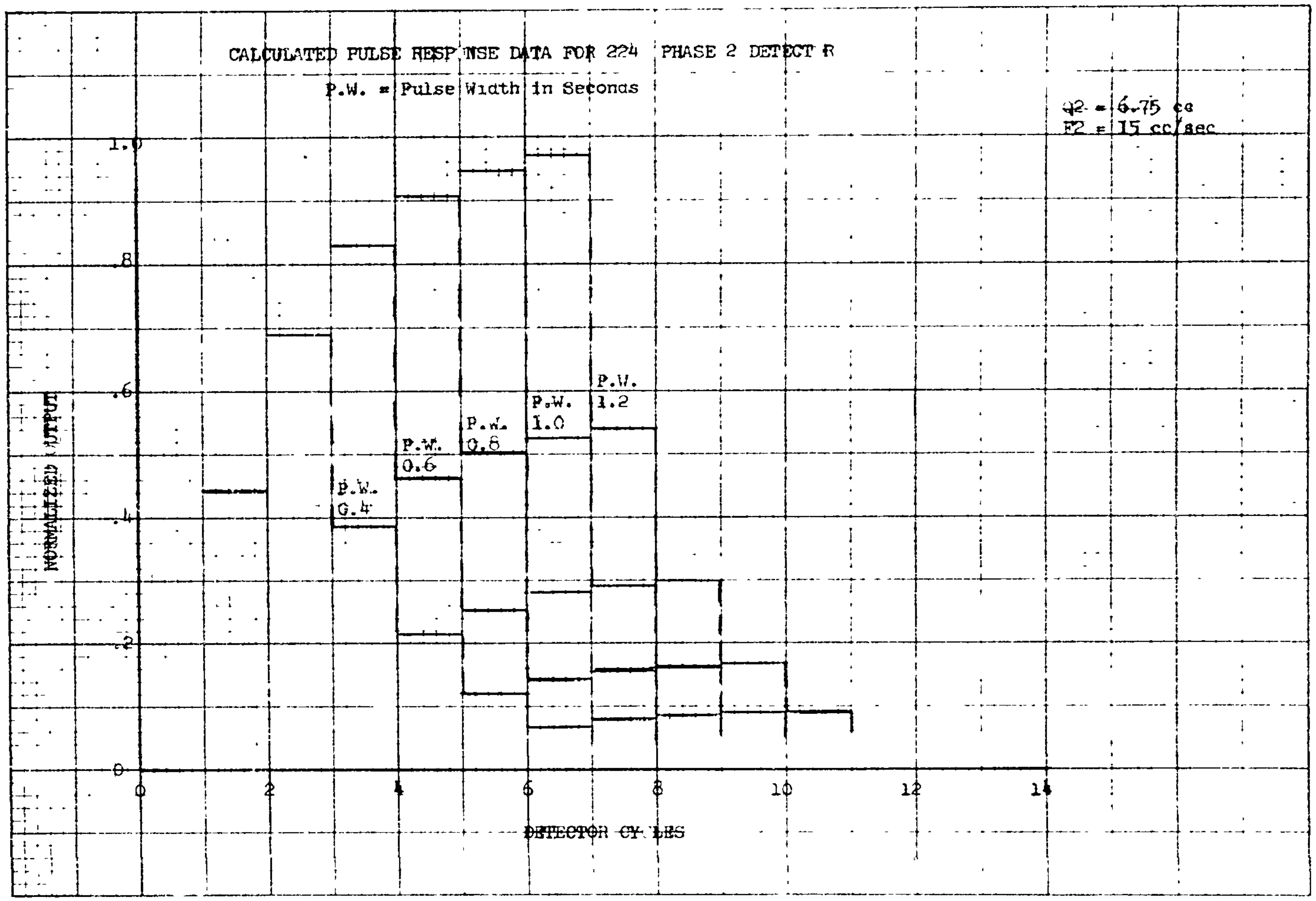


Figure 5-20. Calculated Pulse Response Data for Detectors.

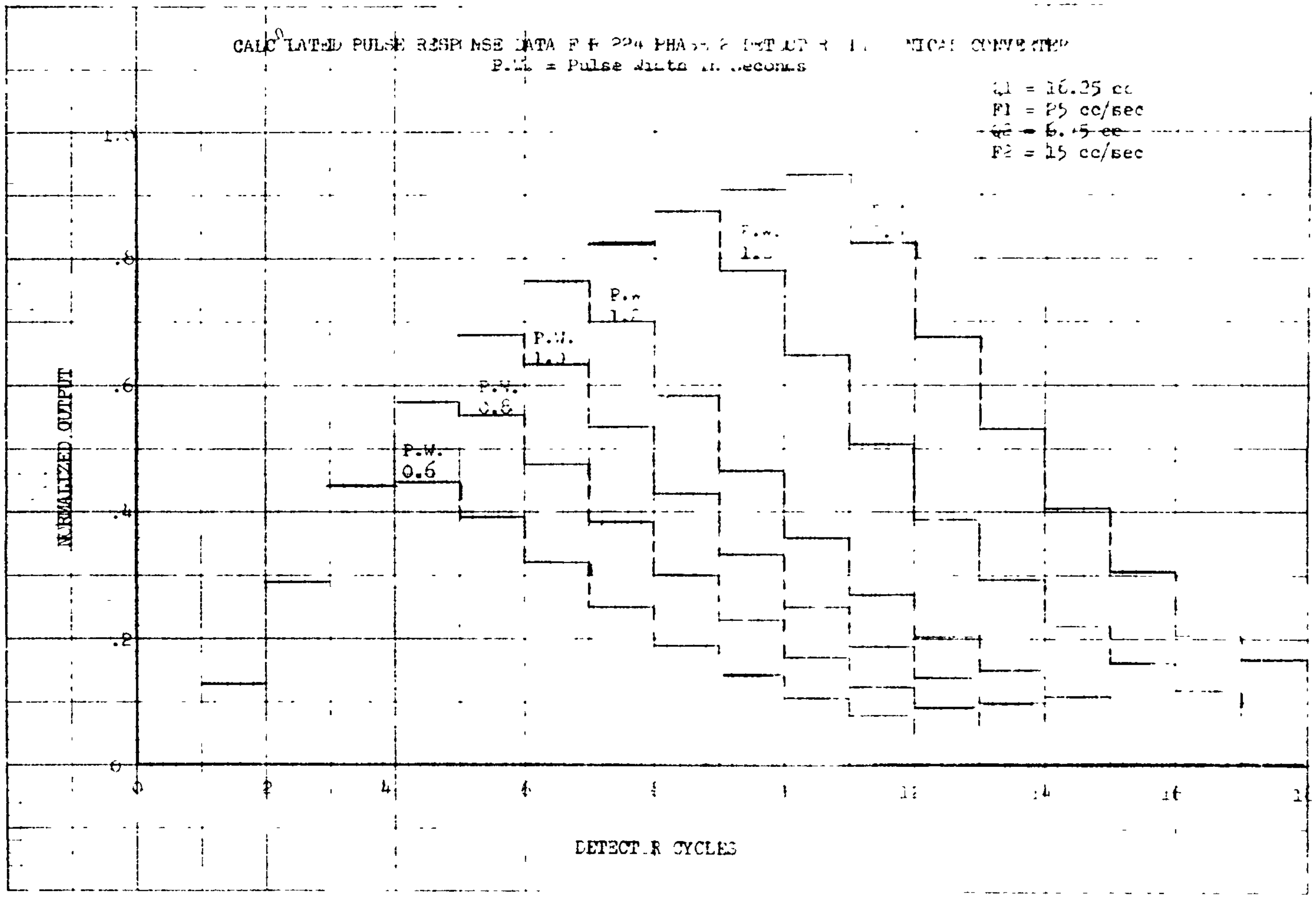


Figure 5-21. Calculated Pulse Response Data for Detectors and Converters

GENERAL ELECTRIC COMPANY
100 PLASTICS AVENUE

ORDNANCE DEPARTMENT
PITTSFIELD, MASS.

PROJECT 224 MEMORANDUM

SUBJECT: Time Response Test Results for 224 Phase IV Detectors

DATE: 8 November 1967

DISTRIBUTION:

JM Anderson
DP Bilyeu
JK Chapman
PE Coffey
SB Dunham
SJ Fusco
RJ Gillmeister
JB Haberl
RW Kenyon
HL Kramer
MH Kurt
EB McCrohan
RF Powers (5)
GF Prehmus
AJ Rider
G. Skala
FW VanLuik

Conclusions

Time response measurements were made on the first three detectors delivered for Phase IV of project 224. Investigations were made to determine the significant factors that effect time response. The conclusions are that the following factors are significant with respect to time response.

1. Length and diameter of passages drilled in block.

2. Valve, flush slot size.

3. Humidifier design.

4. Length and inside diameter of tygon tubing used to connect detector to air inlet.

Detector Response Characteristics

Tests of the time response of the three detectors that are all 5 cps units indicate that they have a significantly longer time response than that measured for the 224 Phase III and 223 detectors. Furthermore the character of the response appears to be that of a double constant rather than a single time constant. Since the major difference in design for Phase IV is the use of passages drilled in the block the conclusion is that the length and diameter of these passages are significant from a time response standpoint.

The average time for these detectors to reach 63% of full scale for a step input of CN was 0.50 seconds. Individual measurements varied as much as 15% about this value.

Valve Flush Slot Size "

The flush slot in the rotary valve is presently 20 mils square. This slot size determines the air that flows through the chamber and humidifier for each detector cycle and therefore the time constant for the humidifier.

Valves with slots that were 25 and 30 mils square were tested with the detector. The average time to reach 63% dropped from 0.50 seconds to 0.41 and 0.35 seconds respectively. However, with the 30 mil slot the vacuum dropped to 6 inches of Hg and could not be regulated.

Humidifier Design

An attempt was made to determine the effects of air flow patterns through the sintered wick of the humidifier by controlling and diverting the flow with metal strips. The results were that no significant change in response was measured.

A different humidifier design was also tried. This humidifier consisted of a coil of dacron wicking in a 3 inch length of 5/16 inch diameter tygon tubing. Air inlet was directly into the humidifier and then to the valve plate. The time for the detector to reach 63% of full response for this humidifier was 0.19 seconds as compared to 0.41 seconds for the regular humidifier and inlet passage design.

As a further indication of response potential, the response of the chamber and valve alone to humid air blown across the valve plate was measured as about 0.10 seconds.

Length and Diameter of Inlet Tubing

Six foot lengths of 3/32, 1/8, 3/16, and 1/4 inch tubing were used to investigate the effects of inlet tube parameters on total detector system time response.

For the regular detector with a 25 mil valve slot the time to reach 63% of full value increased from 0.41 seconds without a tube to 0.51 seconds for the 1/8 inch tube and 0.66 seconds for a 1/4 inch tube. The detector did not operate properly with a 3/32 inch tube since the air flow was restricted to the point where the vacuum could not be regulated.

Similar tests were also run with the 3 inch coiled wick test humidifier. The 63% time response of 0.19 seconds without an inlet tube was increased to 0.30, 0.49, and 0.64 seconds respectively with the 1/8, 3/16, and 1/4 inch tubes.

Design Recommendations for the Phase IV Systems

1. The valve flush slot should be increased in size until limited by pump capacity (about 25 mils square).

2. The air inlet on the surface of the pod should be moved as close to the detector as possible.

3. Air inlet tubing should be 1/8 inch in inside diameter.

4. The hard tubing on the detector air inlet should be decreased in diameter to be compatible with the 1/8 inch tygon tubing.

Recommendations for Further Testing

1. The 10 cycle detector should be tested when available.

2. Both the 5 and 10 cycle detectors should be tested with the gas converters when they become available.

3. The 5 cycle detector should be tested with a laboratory setup providing air inlet directly into the sintered wick humidifier.

A. M. VanBlarcom

A. M. VanBlarcom - Consulting Systems Engineer
Electro-Mechanical Equipment Engineering
Mail 8058 - Ext. 5204

/s

Measured Detector "Time" Constants (ie 63% Time)

Time Constant Sec	Valve Size Mils^2	Detector Conditions: Humidifier Type	Detector Conditions: Inlet Tube	Remarks
.50	20	Metal	None	
.41	25	Metal	None	
.35	30	Metal	None	Max. Vacuum 6" Hg
.51	25	Metal	6' of 1/8" Tygon	
.66	25	Metal	6' of 1/4" Tygon	Detector Sluggish due to pressure drop in tube vacuum 10" Hg
—	25	Metal	6' of 3/32' Tubing	
.19	25	3" Tube 5/16 Diam Wick	None	Direct Input to chamber bypassing passages in block
.30	25	3" Tube 5/16 Diam Wick	6' of 1/8" Tygon	
.64	25	3" Tube 5/16 Diam Wick	6' of 1/4" Tygon	
.41	25	Metal*	None	Humidifier partially blocked
.39	25	Metal*	None	Humidifier blocked
.40	25	Metal*	None	Humidifier flow directed
THIS TENDS TO SHOW THAT THE HUMIDIFIER IS NOT THE MAJOR TIME CONSTANT—OR AT LEAST FLOW IS NOT THROUGH TOTAL AREA				
.10	25	None	None	Response to breath humidity
THIS SHOWS THAT DETECTOR CHAMBER AND VALVE CAN RESPOND RAPIDLY.				
.35	25	Metal*	None	Humidifier blocks W O level
LOCALIZES FLOW AND THEREFORE CUTS T.C. OF WICK AREA.				
.31	25	3" Tube Wick	18" of 3/16" Tygon	
.17	25	3" Tube Wick 1/8" Rod	None	
.28	25	4.5" Tube Wick	18" of 3/16" Tygon	

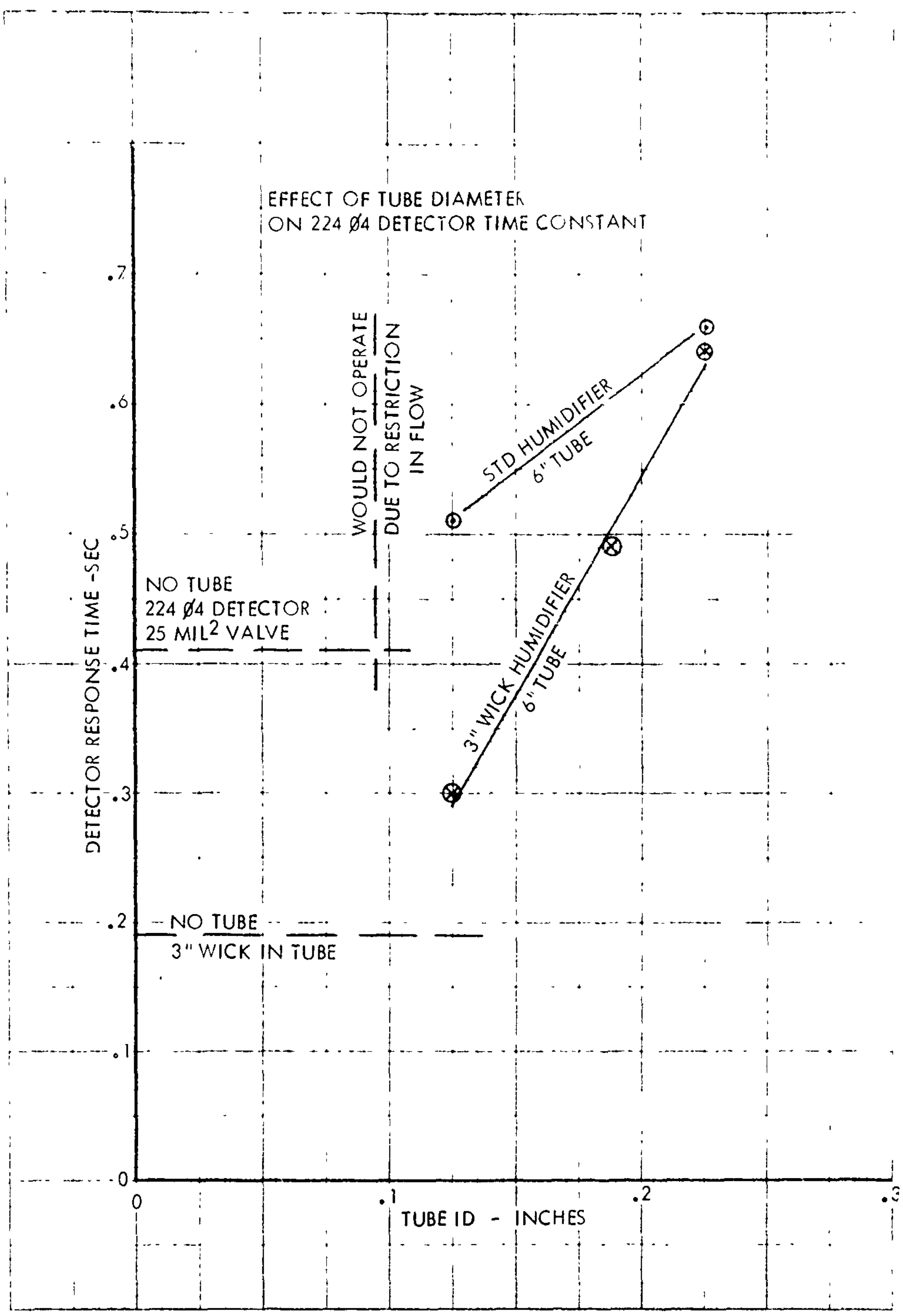


Figure 5-22. Effect of Tube Diameter.

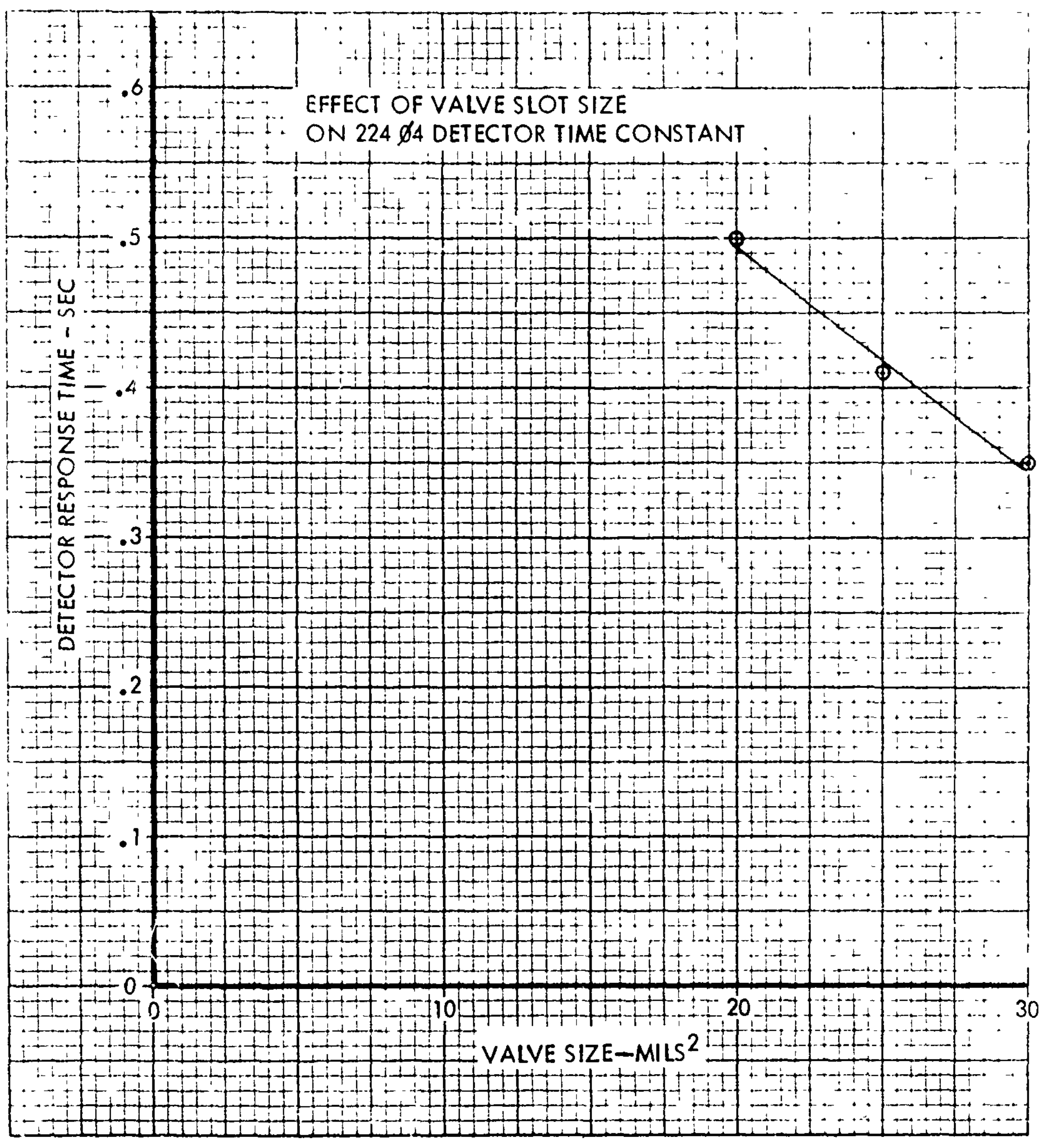


Figure 5-23. Effect of Valve Slot Size.

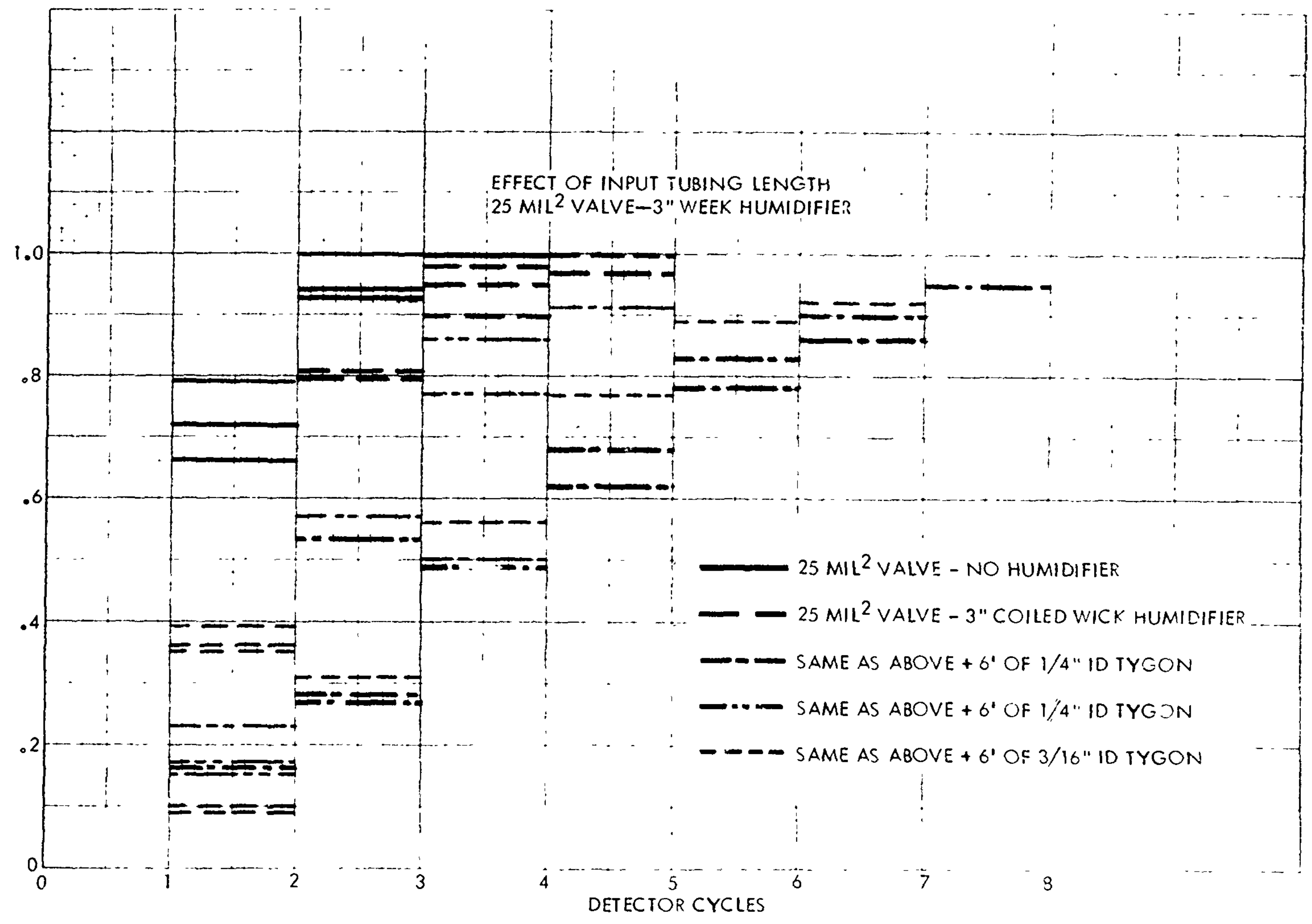


Figure 5-24. Effect of Input Tubing Length with 3-Inch Wick Humidifier.

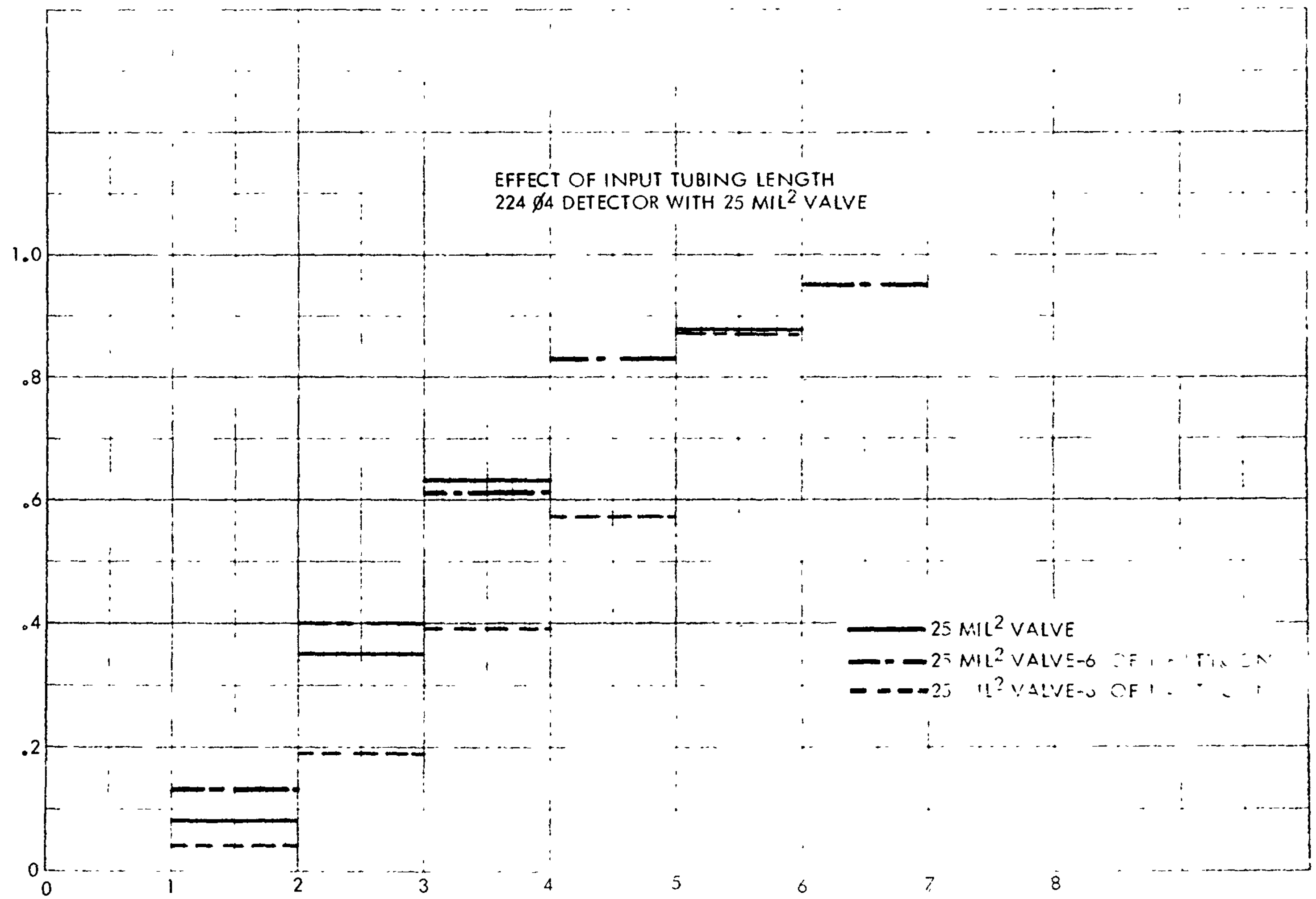


Figure 5-25. Effect of Input Tubing Length.

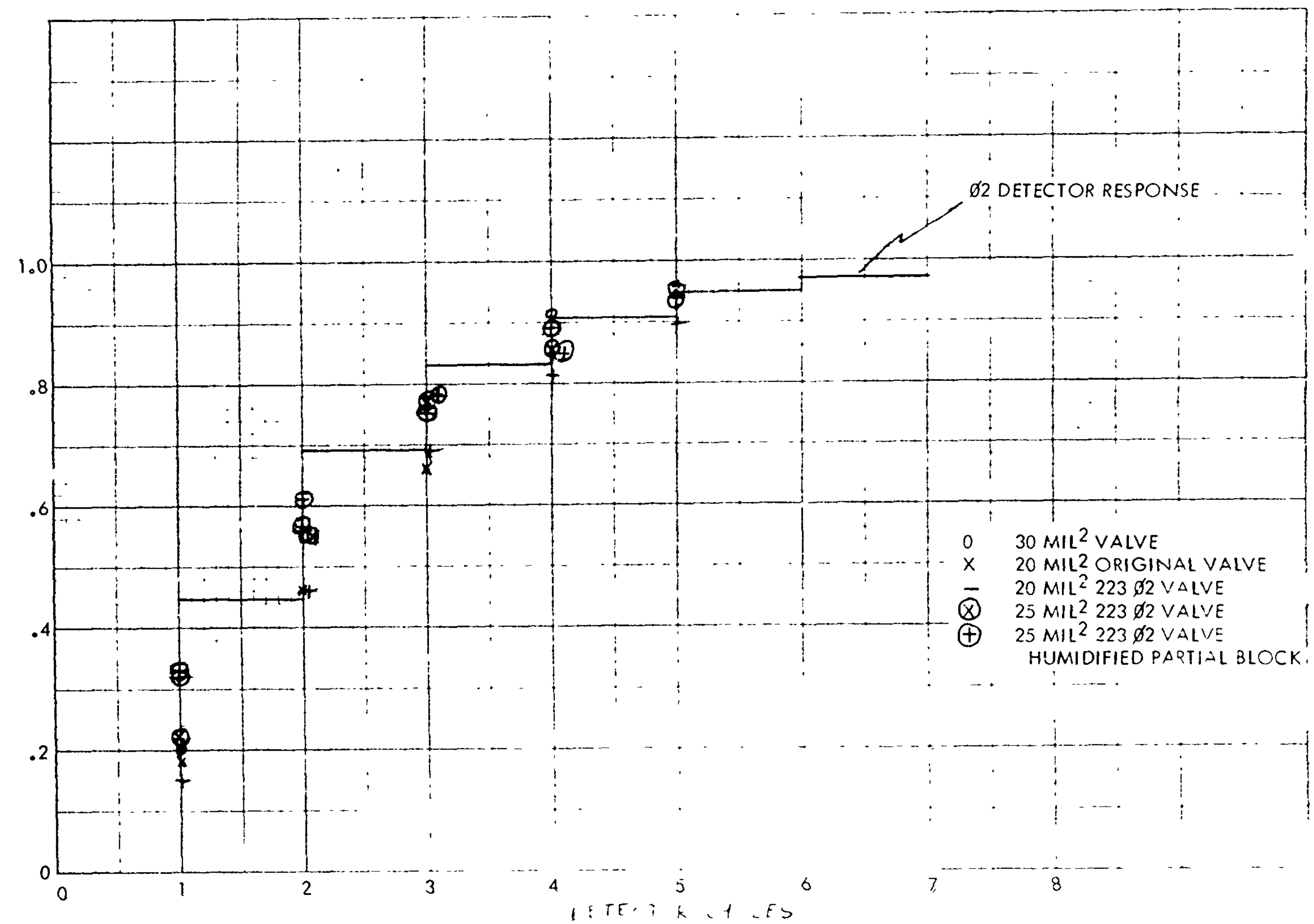


Figure 5-26. Detector Response.

GENERAL ELECTRIC COMPANY
100 PLASTICS AVENUE

ORDNANCE DEPARTMENT
PITTSFIELD, MASS.

PROJECT 224 MEMORANDUM

SUBJECT: Time Response Test Results for 224 Phase IV Detectors with new humidifier wick assembly and for Converter/Detector combination

DISTRIBUTION:

JM Anderson
DP Bilyeu
JK Chapman
PF Coffey
SB Dunham
SJ Fusco
RJ Gillmeister
JB Haberl
RW Kenyon
HL Kramer
MH Kurth
EB McCrohan
RF Powers (5)
GF Prehmus
AJ Rider
G. Skala
FW VanLuik

Test Procedure

Time response tests were run for step inputs of condensation nuclei for the 224 Phase IV detector with its new humidifier wick assembly and for this detector with a converter of the latest design. In order to simulate the installation in the pod, 12 inches of 1/8 inch I.T. tubing was used at the input to the detector for the detector tests and to connect the converter to the detector for the combined tests. Tests were run with both 5 and 10 cycle per second detectors.

Results

Typical detector responses for step input signals are shown on Figure 5-27. These responses represent averages of several runs. This was done to filter detector noise effects.

As can be seen the response is characterized by a delay or transport time and a transient rise time. For purposes of this memo, the transport time is defined as the interval from the time that the step input is applied until the response reaches 30% of maximum.

This was chosen because pulse width is measured between the 30% points in the signal processing program. Transient rise time is defined as the interval from the point where the detector output first starts to rise until it reaches 63% of maximum output. Smooth curves were passed through the staircase output signals in order to measure these times.

Transport and transient rise times for the various configurations tested are summarized in the table below.

TABLE OF TRANSPORT AND TRANSIENT RISE TIMES

224 PHASE IV DETECTOR AND CONVERTER

CONFIGURATION	TRANSPORT DELAY SEC.	TRANSIENT RISE SEC.
10 cps Detector with 12" of 1/8" ID tube	0.3	0.22
5 cps Detector with 12" of 1/8" ID tube	0.5	0.30
10 cps Detector with 12" of 1/8" ID tube and 16 cc converter	1.0	0.60
5 cps Detector with 12" of 1/8" ID tube and 16 cc converter	1.3	0.97

Flow rates as measured for the detectors were 24 and 41 cc per second for the 5 and 10 cycle per second units respectively.

Conclusions

The transient response of the latest detector is more rapid than the response of the previous design. This is due to the decreased volume of the humidifier with the new wick assembly. Humidifier volume has changed from 6.75 to 3.75 cc. The effect of the drilled passages in the block is still apparent when the 224 detector response is compared with the 223 detector response.

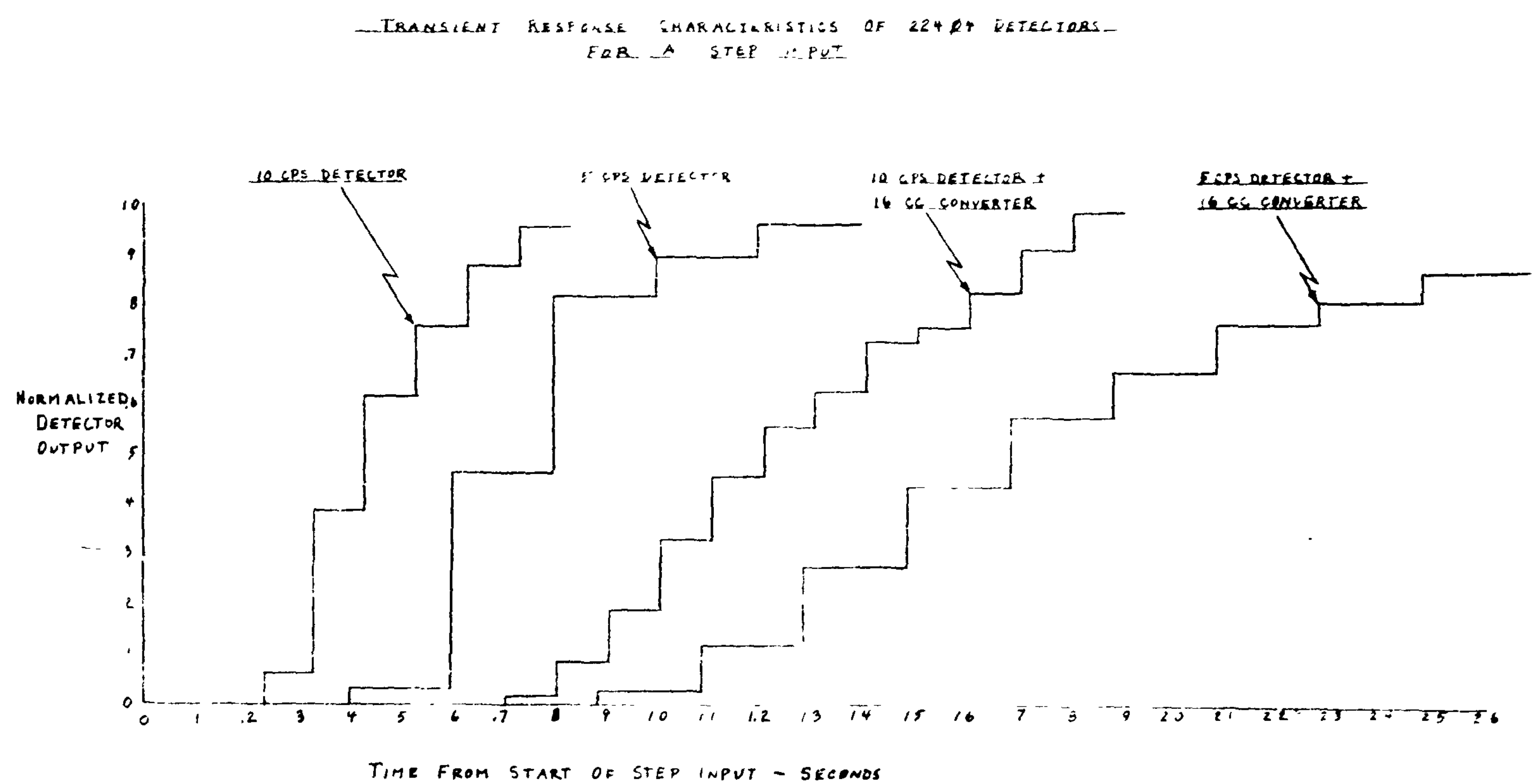


Figure 5-27 Typical Detector Response

The transient rise time of the converter and 10 cps detector is appreciably faster than that of the converter and 5 cps detector. The ratio of the rise times is approximately the same as the ratio of the flow rates which follows theory.

Van Blarcom

A. M. VanBlarcom - Consulting Systems Engineer
Electro-Mechanical Equipment Engineering
Room #8058 - OP 8 - Ext. 5-204

/jt

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified

1. ORIGINATING ACTIVITY (Corporate author)
General Electric Company
100 Plastics Avenue
Pittsfield, Massachusetts 01201

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP
N/A

3. REPORT TITLE
Aircraft Mounted Personnel Detector Chemical

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
LWL-CR-06C66A

5. AUTHOR(S) (First name, middle initial, last name)

6. REPORT DATE	7a. TOTAL NO OF PAGES	7b. NO OF REFS
May 1970	391	None

8a. CONTRACT OR GRANT NO
Contract No. DA-18-001-AMC-983(X)

b. PROJECT NO

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
EACH TRANSMITTAL OF THIS DOCUMENT OUTSIDE THE DEPARTMENT OF DEFENSE MUST HAVE PRIOR APPROVAL OF THE U.S. ARMY LAND WARFARE LABORATORY.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
U.S. ARMY LAND WARFARE LABORATORY
Aberdeen Proving Ground, Maryland 21005

13. ABSTRACT

Two aircraft mounted personnel detector systems were designed, fabricated, checked out, installed on military aircraft and field tested. The systems were demonstrated to be capable of meeting the design criteria of detecting airborne effluents and predicting their locations.

Ground support equipment, spare and repair parts, and operational and maintenance manuals necessary for field and operational support were developed and supplied.

The systems developed on the Phase IV effort were essentially a refined and repackaged version of the Phase II system.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification